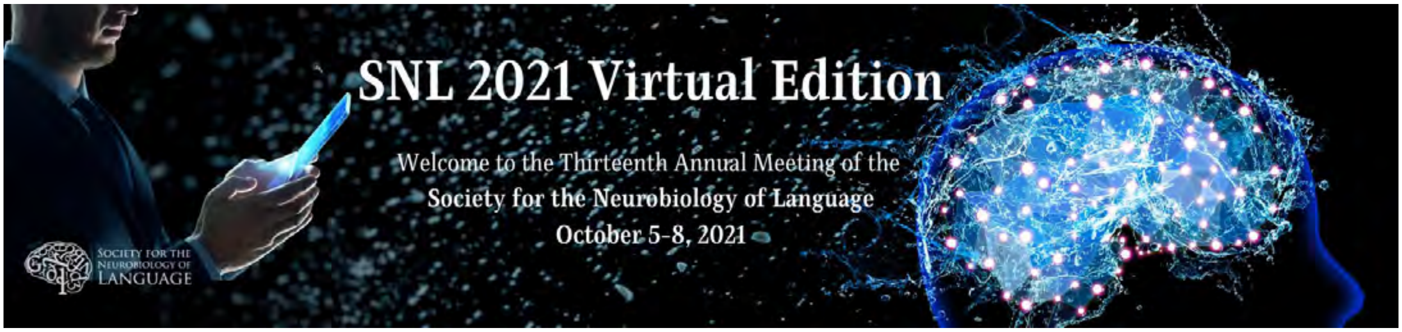


Program

SNL 2021 Virtual Edition

https://2021.neurolang.org/

Welcome to SNL 2021!

Dear Colleagues,

We are excited to announce the Thirteenth Meeting of the Society for the Neurobiology of Language and its second virtual version.

Last year, we found that the online SNL meeting made it possible to reach out to members near and far, and most importantly interested new members and all of those members who normally cannot travel long distances to be part of our exciting meeting.

This year, we have repeated the many online methods for meeting in the virtual SNL world. These worked well before and allowed a variety of ways to exchange the latest scientific ideas.

During the four days of our virtual meeting, you will be able to enjoy an exciting programme with keynote talks by Rosemary Varley, Erich Jarvis and Fernanda Ferreira. Yet again we have three fascinating Symposia: (i) Can we predict responses to language interventions? (ii) Semantic knowledge representations in the anterior temporal lobes and beyond; (iii) What can NLP systems teach us about language in the brain? These will be supplemented by the new Slide Slam sessions which are fantastic new opportunity afforded by the virtual meeting format.

Another highlight of the meeting will be our impressive award winners. Peter Hagoort is this year's recipient of the Distinguished Career Award, generously sponsored by Language, Cognition and Neuroscience. We also look forward to the Early Career Award talk by Adeen Flinker, and the Dissertation Award talk by Sahil Luthra, both awards generously sponsored by Brain and Language to acknowledge young and thriving scientists in the field for their contribution to the neurobiology of language.

The meeting will also offer opportunities to hear about the Society's Journal, and NIDCD Funding for early career investigators.

We would like to acknowledge our sponsors: Neurobiology of Language (The MIT Press) (Gold Sponsor); Brain & Language (Elsevier) (Awards Sponsor); Language, Cognition & Neuroscience (Routledge) (Awards Sponsor); Rogue Research Inc. (Silver Sponsor); The Basque Center on Cognition, Brain and Language (BCBL) (Meeting Sponsor); and Center for Mind and Brain at UC Davis (Meeting Sponsor).

We are looking forward to seeing you all online for an exciting meeting!

Matt Lambon Ralph
Chair, Society for the Neurobiology of Language

SNL 2021 Sessions

The SNL 2021 sessions are listed below and on the Schedule of Events. Also see Navigating the Meeting for more information on finding your way around our new virtual world.

Schedule of Events

Opening Remarks

Keynote Lectures

Rosemary Varley *Autonomy or interdependence of language and non-verbal cognition: the language and thought debate from the perspective of global aphasia*

Erich Jarvis *Evolution and neural mechanisms of vocal learning*

Fernanda Ferreira *What's good enough about good enough language processing?*

Award Lectures

Adeen Flinker - Early Career Award *Intracranial electrophysiology of speech perception and production*

Sahil Luthra - Dissertation Award *A right hemisphere role in talker-specific phonetic processing*

Peter Hagoort - Distinguished Career Award *Carving the neurobiology of language at its joints: the quest for natural kinds*

Symposia

Symposium 1 *Can we predict responses to language interventions? Should we?*

Symposium 2 *Semantic knowledge representations in the anterior temporal lobes and beyond*

Symposium 3 *What can NLP systems teach us about language in the brain?*

Slide Sessions

Slide Session A

Slide Session B

Slide Session C

Slide Session D

Slide Slam Sessions

Slide Slam Session A

Slide Slam Session B

Slide Slam Session C

Slide Slam Session D

Slide Slam Session E

Slide Slam Session F

Slide Slam Session G

Slide Slam Session H

Slide Slam Session I

Slide Slam Session J

Slide Slam Session K

Slide Slam Session L

Slide Slam Session M

Slide Slam Session N

Slide Slam Session O

Other Sessions

Meeting Sponsors

Closing Remarks

Schedule of Events

Times are shown in PDT (America/Los_Angeles) timezone.

Tuesday, October 5	
8:15 - 8:30 am	**Opening Remarks** Join Zoom Webinar
8:30 - 9:30 am	**Keynote: Rosemary Varley** Join Zoom Webinar
10:00 am - 12:00 pm	**Symposium 1: Can we predict responses to language interventions? Should we?** Join Zoom Webinar
12:30 - 3:00 pm	**Slide Slam Session A** Join Zoom Webinar
12:30 - 3:00 pm	**Slide Slam Session B** Join Zoom Webinar
12:30 - 3:00 pm	**Slide Slam Session C** Join Zoom Webinar
3:30 - 5:00 pm	**Slide Session A** Join Zoom Webinar
5:30 - 7:30 pm	**Slide Slam Session D** Join Zoom Webinar
5:30 - 7:30 pm	**Slide Slam Session E** Join Zoom Webinar
Wednesday, October 6	
6:00 - 8:00 am	**Slide Slam Session F** Join Zoom Webinar
6:00 - 8:00 am	**Slide Slam Session G** Join Zoom Webinar
6:00 - 8:00 am	**Slide Slam Session H** Join Zoom Webinar
8:30 - 10:30 am	**Symposium 2: Semantic Knowledge representations in the anterior temporal lobes and beyond** Join Zoom Webinar
11:00 am - 12:30 pm	**Slide Session B** Join Zoom Webinar
1:00 - 2:00 pm	**Neurobiology of Language Journal Session** Join Zoom Webinar
2:30 - 3:30 pm	**NIDCD Funding for Early Career Investigators** Join Zoom Webinar
4:00 - 5:00 pm	**Keynote: Erich Jarvis** Join Zoom Webinar
5:30 - 7:30 pm	**Slide Slam Session I** Join Zoom Webinar
5:30 - 7:30 pm	**Slide Slam Session J** Join Zoom Webinar
Thursday, October 7	
6:00 - 8:00 am	**Slide Slam Session K** Join Zoom Webinar
6:00 - 8:00 am	**Slide Slam Session L** Join Zoom Webinar

6:00 - 8:00 am	**Slide Slam Session M** Join Zoom Webinar
8:30 - 9:30 am	**Keynote: Fernanda Ferreira** Join Zoom Webinar
10:00 - 10:45 am	**Early Career Award: Adeen Flinker** Join Zoom Webinar
10:45 - 11:15 am	**Dissertation Award: Sahil Luthra** Join Zoom Webinar
12:00 - 1:00 pm	**Business Meeting** Join Zoom Webinar
1:00 - 2:00 pm	**Early Career Event** Join Zoom Webinar
2:30 - 4:30 pm	**Slide Slam Session N** Join Zoom Webinar
2:30 - 4:30 pm	**Slide Slam Session O** Join Zoom Webinar
2:30 - 4:30 pm	**Slide Slam Session P** Join Zoom Webinar
5:00 - 6:30 pm	**Slide Session C** Join Zoom Webinar
Friday, October 8	
6:00 - 8:00 am	**Symposium 3: What can NLP systems teach us about language in the brain?** Join Zoom Webinar
8:00 - 9:30 am	**Slide Session D** Join Zoom Webinar
10:30 - 11:15 am	**Distinguished Career Award: Peter Hagoort** Join Zoom Webinar
12:00 - 2:30 pm	**Slide Slam Session Q** Join Zoom Webinar
12:00 - 2:30 pm	**Slide Slam Session R** Join Zoom Webinar
12:00 - 2:30 pm	**Slide Slam Session S** Join Zoom Webinar
2:30 - 2:35 pm	**Closing Remarks** Join Zoom Webinar

Navigating the Meeting

Welcome to SNL 2021, our second virtual edition of the annual SNL meeting. We are committed to providing a virtual experience designed to deliver the high-quality research that you have come to expect at SNL meetings, featuring Keynote Lectures, Symposia, Slide Sessions, Slide Slams, Award Talks, and a Student Session.

Sessions

Below are descriptions of session formats and how to access and participate in sessions. One advantage of the virtual meeting is that recordings of all presentations will be accessible online until January 31, 2022. You will never have to miss a session!

Poster Sessions have been replaced with Slide Slams.

Keynote Lectures, Symposia, and Award Talks

The Keynote Lectures, Symposia, and Award Talks will be presented live over Zoom Webinar. The presentations will be live captioned.

Slide Sessions

Slide Sessions are presented in a “simulated live” format. A pre-recorded presentation is played in a Zoom Webinar. During the presentation, attendees can pose questions via the Q & A function, which the speaker may address during the Question and Answer period at the end of each presentation. Question and Answer periods will be simultaneously interpreted in ASL, with English auto-captioning in Zoom. All pre-recorded presentations are open captioned. All pre-recorded presentations are open captioned. Video recordings will be available online after each session and are downloadable until January 31, 2022.

Slide Slam Sessions

For this year, Slide Slams replace Poster presentations. Slide Slams are 5-minute pre-recorded presentations played in a “simulated live” format in a Zoom Webinar. All of the Slide Slams in each session will be played back-to-back with Question and Answer period at the end of the session. Question and Answer periods will be simultaneously interpreted in ASL, with English auto-captioning in Zoom. All pre-recorded presentations are open captioned. All pre-recorded presentations are open captioned. Video recordings will be available online after each session and are downloadable until January 31, 2022.

How to Join a Zoom Webinar

To attend any session, join the Zoom Webinar by clicking on the 'Join Zoom Webinar' link for that session. Zoom links can be found:

- On the Schedule of Events.
- At the top of the session’s page.
- In this Program PDF.
- In Daily Emails sent to all registrants.

Sponsors

SNL 2021 would not be possible without the support of our wonderful sponsors, many of whom have prepared special videos for SNL attendees. Please be sure to visit our Meeting Sponsors page to learn more.

Creating a Personal Itinerary

To help you plan your time at SNL 2021, the meeting website lets you bookmark sessions you're interested in. Here's how:

1. Log In using your SNL Account credentials (email and password).
2. Navigate to any session page and click the bookmark icon at the top of the page. A green bookmark icon means the session has been bookmarked.
3. Click the View My Itinerary link after bookmarking a session to see your bookmarked sessions.

To remove a bookmark, click the green bookmark icon.

Set Your Timezone

Session times are displayed in the Schedule of Events and at the top of each session page. To see session times in your timezone, log in and click Set Timezone at the top of the page.

If you're *not* logged in, or have *not* set your timezone, times are displayed in Pacific Daylight Time (PDT).

Tuesday, October 5, 8:15 - 8:30 am PDT Join Zoom Webinar

Opening Remarks

The SNL Chair will welcome SNL members to the meeting and give overview of what to expect at SNL 2021 (Virtual Edition).

The Keynote Address by Rosemary Varley will immediately following the Opening Remarks. You can remain on the same Zoom Webinar to attend the Keynote Address.

Tuesday, October 5, 8:30 - 9:30 am PDT Join Zoom Webinar

Keynote – Rosemary Varley

Autonomy or interdependence of language and non-verbal cognition: the language and thought debate from the perspective of global aphasia

Speaker: **Rosemary Varley**, *University College London*

Language is more than a capacity used for interpersonal communication. Linguistic representations can also form a part of reasoning in other cognitive domains. However, it is unclear whether the role of language in non-verbal domains is a necessary one, or whether it represents an optional resource that is recruited by neurotypical people in the face of challenging or highly intentional processing demands. One method to explore language reuse in domains such as calculation, mental state reasoning or event perception is to examine the abilities of people with severe aphasia. In a series of studies, we have shown residual capacity despite profound aphasia in such domains. In this talk, I will outline these findings and show how they inform questions regarding neural reuse/shared resource, as opposed to specialized neurocognitive mechanisms dedicated to specific functions.

About Rosemary Varley

Rosemary Varley is Professor of Acquired Language Disorders in the Division of Psychology & Language Sciences at University College London. Previous posts have included work in the NHS, and appointments at the Universities of Hong Kong and Sheffield. Her research is funded by The Stroke Association, The Alzheimer's Society, and UK Research Councils (ESRC and AHRC). Most of her work is directed to the investigation of post-stroke language impairment, but she has also explored language disruptions in the dementias and schizophrenia. Major research themes are exploration of grammatical processing and speech control impairments (apraxia) from the perspective of usage-based approaches to language, as well as their application in other domains of psycholinguistics, such as bilingualism. This work has informed interventions for post-stroke speech and language disorders, with a focus on intensive behavioural therapy in combination with non-invasive brain stimulation. A second core theme – and the topic of this talk – is exploration of residual reasoning ability in individuals with severe aphasia. This evidence informs debates as to the autonomy or, alternatively, the interconnectedness of language with other cognitive mechanisms in the mature/adult cognitive architecture.

Wednesday, October 6, 4:00 - 5:00 pm PDT Join Zoom Webinar

Keynote – Erich Jarvis

Evolution and neural mechanisms of vocal learning

Speaker: **Erich Jarvis**, *Rockefeller University*

Vocal learning is one of the most critical components of spoken language. It has evolved rarely, several independent times among mammals and birds. Although all vocal learning species are distantly related and have closer relatives that are non-vocal learners, humans and the vocal learning birds have evolved convergent forebrain pathways that control song and speech imitation and production. Here I will present an overview of the various biological hypothesis of what makes vocal learning and spoken language special, how it evolved, and what differs about the mechanisms compared to other behavioral traits. We used comparative genomics and transcriptomics to discover convergent changes in genes in song learning pathways in birds and speech pathways in humans that control brain connectivity, neural activity, and synaptic plasticity. The specialized regulation is associated with convergent accelerated regions in their regulatory regions, that have binding sites by a set of transcriptive factors with differential regulation specific to vocal learning circuits. To explain these findings, I propose a motor theory of vocal learning origin, in which brain pathways for vocal learning evolved by brain pathway duplication of an ancestral motor learning pathway, using mostly the same genes, but with some divergences in gene regulation via sequence and epigenetic changes, that control divergent connectivity and other specialized functions to rapidly integrate auditory input with vocal motor output.

About Erich Jarvis

Erich Jarvis, Ph.D., studies the molecular and genetic mechanisms that underlie vocal learning, using birdsong as a primary model for human spoken language. He has developed an integrative approach that combines computational, behavioral, physiological, and molecular techniques to uncover not only the neural genetics of vocal learning, but also the evolution of this complex behavior. Dr. Jarvis's studies comparing neural structure and gene expression in songbirds and other species have led him to theorize that the brain pathways for vocal learning in both birds and humans likely evolved from a motor circuit common to all vertebrates. By harnessing new technologies to elucidate the biological mechanisms that underlie vocal learning, Dr. Jarvis is further exploring how neural circuits are established.

Thursday, October 7, 8:30 - 9:30 am PDT Join Zoom Webinar

Keynote – Fernanda Ferreira

Fernanda Ferreira's Keynote Address is generously sponsored by *Neurobiology of Language* *(The MIT Press)*.

What's good enough about good enough language processing?

Speaker: **Fernanda Ferreira**, *Department of Psychology and Graduate Program in Linguistics, University of California, Davis*

People who are given the sentence "While Mary bathed the baby played in the crib" will say "yes" 50% of the time to a question about whether Mary bathed the baby. Comprehenders also misinterpret passive sentences such as "The dog was bitten by the man", deriving the interpretation consistent with world knowledge instead of the one licensed by the syntactic structure. But what is it that is merely good enough: the syntactic parse, the interpretation derived from it, or both? In this presentation I will review recent work which shows that misinterpretations are not due to a failure to build a correct syntactic structure but instead arise from competition among multiple interpretations built incrementally during online processing. Good enough processing, then, turns out to be entirely compatible with the assumption that the parser builds full and accurate syntactic representations, and it links misinterpretations to systems that build meaning.

About Fernanda Ferreira

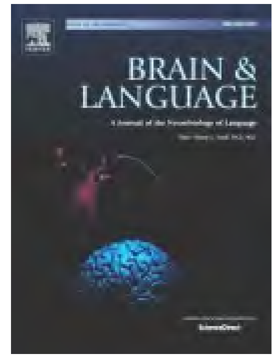
Fernanda Ferreira, Ph.D., is Professor of Psychology and Member of the Graduate Program in Linguistics at the University of California, Davis. Her research focuses on discovering the mechanisms that enable humans to understand and generate language in real time and in cooperation with other cognitive systems. She is a Fellow of the American Psychological Society, the Cognitive Science Society, and the Royal Society of Edinburgh, and in 1996 she received the American Psychological Association's Distinguished Scientific Award for Early Career Contribution to Psychology (Cognition and Human Learning). From 2006-2010 she was the Editor-in-Chief of the Journal of Experimental Psychology: General, and she has also served as an Associate Editor for the Journal of Memory and Language and Cognitive Psychology. In the past year she helped found a new, fair open access journal called Glossa Psycholinguistics, for which she and Brian Dillon serve as Editors-in-Chief. She has been a member of the Linguistics Panel of the National Science Foundation and is currently a standing member of the National Institutes of Health Study Section on Language and Communication. When she is not doing psycholinguistics, she enjoys running and reading.

Thursday, October 7, 10:00 - 10:45 am PDT Join Zoom Webinar

Early Career Award – Adeen Flinker

The Society for the Neurobiology of Language is pleased to announce the 2021 Early Career Award recipient: Adeen Flinker

The Early Career Award is generously sponsored by *Brain & Language.*



Intracranial electrophysiology of speech perception and production

Speaker: **Adeen Flinker**, *Assistant Professor, Department of Neurology, NYU*

The seamless process of perceiving speech and then fluently producing a response requires a cascade of neural processing across cortex. Among the most fundamental, and highly debated, principles of the neurobiology of language are the nature of hemispheric asymmetries in speech perception as well as the unique role of the Inferior Frontal Gyrus in speech production. In this talk, I will present how leveraging computational techniques together with temporally resolved neural recordings can shed light on these principles. I will provide a testable computational framework for speech hemispheric asymmetries as well as argue that the Inferior Frontal Gyrus integrates information across cortices and is chiefly active prior to articulation per se.

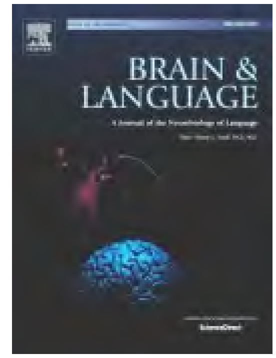
About Adeen Flinker

Adeen Flinker received his PhD in Neuroscience from the University of California at Berkeley in 2012. After completing post-doctoral research at New York University, he joined the New York University School of Medicine as an Assistant Professor of Neurology in 2017. He has appointments with the NYU Neuroscience Institute, NYU Biomedical Engineering and NYU Cognition and Perception.

Dr. Flinker's research focuses on the electrophysiology of speech perception and production. He leverages behavioral, non-invasive and invasive electrophysiology in humans to tackle basic questions in the perception and production of speech. During his PhD work, he used Electrocorticographic (ECoG) recordings over Broca's area to establish that the region is not active during word articulation but rather integrates information from temporal cortices prior to articulation and constructs an articulatory plan which is forwarded to motor cortices. The detailed characterization of the spatiotemporal dynamic in the inferior frontal cortex prior to speech articulation, as well as subsequent suppressed temporal cortex responses to self-generated utterances at a millimeter scale have been since replicated across many laboratories. During his postdoctoral research, he tackled the question of hemispheric cortical asymmetries in speech by providing a novel computational approach to characterize the acoustic space that drives differential cortical responses, unifying previous prevailing models. His approach was tested in psychophysical dichotic paradigms, non-invasive neurophysiology experiments (MEG) as well as neurosurgical recordings (ECoG and sEEG). Dr. Flinker currently oversees ECoG recordings at NYU and his lab focuses on clinical and basic intracranial electrophysiology of language. His research has been published in top journals and is funded by three large NIH grants and a collaborative computational neuroscience NSF award.

Thursday, October 7, 10:45 - 11:15 am PDT Join Zoom Webinar

Dissertation Award – Sahil Luthra



The Society for the Neurobiology of Language is pleased to announce the 2021 Dissertation Award recipient: Sahil Luthra

The Dissertation Award is generously sponsored by *Brain & Language.*

A right hemisphere role in talker-specific phonetic processing

Speaker: **Sahil Luthra**, *University of Connecticut*

The role of the right hemisphere in phonetic processing is thought to be relatively minimal, at least in comparison to the role of the left hemisphere. However, the right hemisphere is known to play a critical role in vocal identity processing, a fact that is striking given that the acoustic-phonetic details of the speech signal can differ substantially between talkers. In this talk, I will describe evidence from fMRI that the right hemisphere – and more specifically, the right posterior temporal cortex – plays a role in helping listeners adapt to the idiosyncratic ways that different talkers produce their speech sounds. Specifically, I will describe evidence that (1) talker information and phonetic detail are simultaneously represented in the functional activation patterns of the right superior temporal sulcus and that (2) the process of conditioning phonetic identity on talker information is supported by the coordinated activity of a left-lateralized phonetic processing system and a right-lateralized talker processing system. Overall, these data clarify the neurobiological mechanisms through which listeners accommodate talker-specific phonetic variation and may point to potential subclinical impairments in patients with right hemisphere damage.

About Sahil Luthra

Sahil Luthra completed his Ph.D. in Psychological Sciences at the University of Connecticut in August 2021. He will move to Carnegie Mellon University as a postdoctoral researcher in September, where he will study the neural basis of auditory selective attention.

The goal of Dr. Luthra's research program is uncovering how our prior knowledge guides our in-the-moment perception of language. He uses a combination of neuroimaging, behavioral, and computational approaches to address this challenge.

Dr. Luthra has published several articles related to this theme. These include a recent behavioral study that resolves a decades-old debate about lexical feedback in spoken word recognition (Luthra et al., 2021, Cognitive Science), a study of the neural basis for lexically-guided perceptual learning (Luthra et al., 2020, J. Cognitive Neuroscience), and computational investigations of predictive processing and predictive coding (Luthra et al., 2021, Psychonomic Bulletin & Review). Recently, Dr. Luthra published a single-author theoretical review of the role of the right hemisphere in accommodating the phonetic variability that exists between talkers in Neurobiology of Language (Luthra, 2021), and he further explored this issue in his dissertation work.

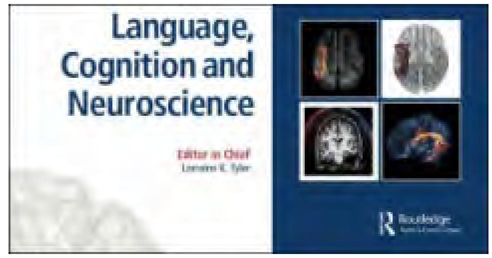
Dr. Luthra is also an active practitioner and advocate of open science as well as clear science communication across disciplinary boundaries. He is strongly committed to promoting diversity, equity, and inclusion.

Honorable Mention

Kiefer Forseth, *UT Health Science Center at Houston*
Mariya Toneva, *Carnegie Mellon University*

Friday, October 8, 10:30 - 11:15 am PDT Join Zoom Webinar

Distinguished Career Award – Peter Hagoort



The Society for the Neurobiology of Language is pleased to announce the 2021 Distinguished Career Award recipient: Peter Hagoort

The Distinguished Career Award is generously sponsored by *Language, Cognition and Neuroscience.*

Carving the neurobiology of language at its joints: the quest for natural kinds

Speaker: **Peter Hagoort**, *Professor of Cognitive Neuroscience, Radboud University, The Netherlands*

Carving nature at its joints means that we have to discover the organizational principles that determine the structure of the domain we are interested in. The challenge for the neurobiology of language is to determine how we have to carve up the human language capacity in terms of its natural kinds, how to carve up the brain in its basic structural and functional components, and finally to determine the mapping relation between the natural kinds on both sides. I will argue that our current way of doing this is not without problems. For instance, Broca's area and Wernicke's are are not natural kinds at the level of neuroanatomy. Language is not a natural kind either. Hence it doesn't make sense to aim at localizing the language system. Moreover a one-to-one mapping (one area one function) between language and brain is neurophysiologically implausible. Making progress in the neurobiology of language requires a stance on the natural kinds and the mapping relations. I will discuss some possible answers to the quest for natural kinds.

About Peter Hagoort

Prof. Dr. Peter Hagoort received his Ph.D. in 1990 from Radboud University in The Netherlands and currently holds the position of full Professor of Cognitive Neuroscience at that institution. A world leader in cognitive neuroscience, he has served as the Director of the Max Planck Institute for Psycholinguistics (MPI), Nijmegen since 2006 and the Director of the Donders Centre for Cognitive Neuroimaging (DCCN) since 1999. His own research group on the Neurobiology of Language is hosted at both the DCCN and the MPI. Hagoort is well known in the SNL community for his early work in the electrophysiology of syntactic processing, his Memory, Unification, and Control (MUC) framework, as well as influential work on the neurobiology of pragmatics, neuromodeling, and emotional aspects of language processing. A founding member of SNL, he has previously served as president of the society and organized the 2014 SNL annual meeting in Amsterdam..

Wednesday, October 6, 1:00 - 2:00 pm PDT Join Zoom Webinar

Neurobiology of Language Journal Session

The Society's Journal *Neurobiology of Language*: Q&A with the Editors-in-Chief

Speakers:

Steven Small, *School of Behavioral and Brain Sciences, University of Texas at Dallas, USA*
Kate Watkins, *Department of Experimental Psychology, University of Oxford, UK*

With MIT Press, SNL launched the new *Neurobiology of Language* journal in April 2019 and the first issue was completed in January 2020. The journal is online only and fully open access, with very reasonable article processing charges and reductions to authors who are members of SNL.

In this session, the Editors-in-Chief will briefly describe the processes involved in publishing at the journal, what we ask of our handing editors and reviewers. We will explain some of the features we have implemented, for example, double-blind reviewing, consensus reviewing, registered reports, early access, etc. We will then open the virtual floor to the audience for questions. What would you like to know about the publishing process? What features would you like to see implemented at the new journal? What do you think of the current features? All welcome.

Neurobiology of Language

Wednesday, October 6, 2:30 - 3:30 pm PDT Join Zoom Webinar

NIDCD Funding Session

NIDCD Funding for Early Career Investigators

Speaker: **Andrea B. Kelly, PhD**, *Scientific Review Officer, Scientific Review Branch, Division of Extramural Activities, National Institute on Deafness and Other Communication Disorders, National Institutes of Health*

This session will provide information for early-career investigators seeking to obtain a grant from the National Institute on Deafness and Other Communication Disorders (NIDCD) for research focused on one or more of the areas within NIDCD’s scientific mission: speech, language, voice, hearing, balance, smell, and taste. It will provide an overview of the submission and review of applications for fellowships (F30, F31, and F32), career development awards (K01, K23, etc.), the loan repayment program (L30), and the NIDCD-specific early-career research award (R21), followed by an ample question-and-answer period.

About Andrea B. Kelly

Dr. Kelly earned a Bachelor of Science degree in biology from Cornell University and a Master’s and PhD in neuroscience from the University of Southern California. She spent several years contracting as a science writer and project manager to NIH’s National Institute on Aging, National Cancer Institute, and Center for Scientific Review. In 2012 she became a Scientific Review Officer, overseeing review of grant applications in a number of study sections, including Language and Communication and Communication Disorders Review Committee. She spends her spare time with her husband, mostly grown-up kids, and a host of four-pawed dependents.

Thursday, October 7, 12:00 - 12:30 pm PDT Join Zoom Webinar

SNL Business Meeting

Join the SNL Board of Directors for the Annual Business Meeting. SNL leadership will review what the Society has accomplished in 2021 and discuss the outlook and priorities for 2022. The Business Meeting is an opportunity for SNL members to ask questions of the SNL Board and bring up issues of concern to the general membership.

You may send questions before the start of the Business Meeting to info@neurolang.org.

Thursday, October 7, 1:00 - 2:00 pm PDT Join Zoom Webinar

Early Career Event

Academia vs. Industry: The Ultimate Choice

Speakers:
Tal Linzen, *Assistant Professor of Linguistics, New York University*
Adina Williams, *NYC Research Scientists, Facebook AI Research*
Leila Wehbe, *Assistant Professor, Carnegie Mellon University*
Andrew Lampinen, *Research Scientist, DeepMind*

Moderator: **Esti Blanco-Elorrieta**, *Harvard University*

Whether to stay in academia or go into industry is a question most PhD and Post-docs grapple with at one point or another of their careers. In this session, we will hear the experiences of two people who made each choice, covering topics such as what they like and don't like of the path they chose and what factors contributed to their choice. Then, we will open the floor for questions from attendees so that they have a chance to ask their doubts, ask about specific opinions, etc.

Tuesday, October 5, 10:00 am - 12:00 pm PDT   Join Zoom Webinar

Symposium 1 – Can we predict responses to language interventions? Should we?

Organizers: **Thomas M.H. Hope**[1] & **Jenny Crinion**[1]; [1]*University College London*
Presenters: **Jade Digman**, **Nadine Martin**, **Janina Wilmskoetter**, **Anne Billot**, **Sigfus Kristinsson**, **Thomas Hope**

Traditional group studies of language (re)learning often fail to capture individuals' variance in response and in the case of aphasia (acquired language disorder post stroke) we frequently see much stronger benefits in individuals than the group-level effects might suggest. If these individual effects are systematic and repeatable, they suggest that language learning (treatment) studies' efficiency might be improved, perhaps dramatically, by targeting interventions to those who are most likely to benefit. This symposium aims to bring together those working (or interested in working) in this emerging field, seeking consensus on its key methodological and ethical challenges. We will ask whether and how we can derive credible, predictive results from the typically small samples employed in this domain. And we will consider how best to address patients' concerns that these results might eventually be used to withhold treatments from those judged unlikely to benefit from them.

Talks

Behavioural predictors of aphasia recovery and treatment response

Jade Digman[1], Amy Rodriguez[2], Kate O'Brien[1], Penni Burfein[1,3], David Copland[1]; [1]University of Queensland, Australia, [2]Centre for Visual and Neurocognitive Research, Atlanta, USA, [3]Surgical Treatment and Rehabilitation Service, Herston, Australia

Individual response to aphasia treatment is highly variable and there is no current method that can be applied clinically to accurately identify treatment response for individuals prior to therapy. In addition to baseline demographic, behavioural and brain-related predictors, measuring early behavioural treatment response may provide a simple method for predicting overall treatment outcome. We examined the relationship between early naming probe accuracy (after 3 hours of impairment therapy) and treatment outcome for 32 individuals with chronic post-stroke aphasia. Participants received 48 hours of impairment, functional, computer and group-based therapy with therapy primarily targeting word retrieval. Linear regression models including the factors lexical-semantic function, age, and early probe accuracy demonstrated that early probe accuracy was a significant predictor of treatment outcome. These findings will be discussed in relation to clinical applications and other potential predictors including functional and structural brain imaging.

A computational account of naming impairments in aphasia, including model-based diagnosis, treatment, and post-treatment assessment.

Nadine Martin[1], Julie Schlesinger[1], Jessica Obermeyer[2], Robert Wiley[2], Gary Dell[3]; [1]Temple University, USA, [2]University of North Carolina, USA, [3]University of Illinois, USA

Recent treatments for word production impairments in aphasia have targeted properties of lexical activation, following the Semantic-Phonological model's characterization of naming impairments as slowed transmission or poor maintenance of activation that supports word retrieval. We demonstrated effects of impairment to these activation parameters using picture naming after a response delay. We examined the Semantic-Phonological model's account further in a treatment for BD82, whose naming accuracy increased and rate of nonword productions decreased after a 5-second delay (the hallmark of a transmission deficit). We identified parameters of the model that simulated her pre-treatment response profile at the 1-second delay. After treatment, naming accuracy increased after the 1-second delay and nonword errors decreased significantly. We fit this pattern to the model by increasing the weight of the Phonological parameter from its pre-treatment setting. We discuss the potential of this model to predict changes in naming following treatments that directly target lexical activation.

Using residual neural networks to predict aphasia recovery after stroke

Janina Wilmskoetter[1], Leonardo Bonilha[1]; [1]Medical University of South Carolina, USA

Individuals with post-stroke aphasia oftentimes present significant variations in recovery, i.e., response to language treatment. Stroke lesion characteristics (such as location, volume, chronicity) only partially explain these observed inter-individual differences. Here, we postulate that aphasia severity and recovery depend on the degree of brain health beyond the stroke lesion, with brain health being defined as the integrity of preserved brain tissue. We will discuss common structural brain pathologies (i.e., small vessel brain disease), and their effect on aphasia recovery that take place independently from the primary stroke lesion. Further, we will discuss how these pathologies may cause variations in the topology of residual neural networks (i.e., decline in long-range white matter fibers, direct connections; and the controllability of brain networks). Our research indicates that personalized rehabilitation may be possible by shifting our focus from what is lost (lesioned brain areas) to what is preserved (residual brain areas).

Multimodal behavioral and neural data predict response to treatment in post-stroke aphasia

Anne Billot[1], Stan Lai[1], Maria Varkanitsa[1], Emily Braun[1], Brenda Rapp[2], Todd Parish[3], Ajay Kurani[3], James Higgins[3], David Caplan[4], Cynthia Thompson[1], Prakash Ishwar[1], Margrit Betke[1], Swathi Kiran[1]; [1]Boston University, USA, [2]Johns Hopkins University, USA, [3]Northwestern University, USA, [4]Harvard Medical School, USA

In this study, we use machine learning models to compare the independent and complementary prognostic role of initial severity of language impairments, demographics and structural/functional integrity of the brain in predicting response to language treatment after a stroke. 55 patients with aphasia

were were characterized as responders or nonresponders to treatment based on their percent change in treatment probe accuracy. Support Vector Machine (SVM) and Random Forest (RF) models were constructed to predict treatment response labels. Input features sets included aphasia severity, cognitive composite scores, demographic and multimodal neuroimaging data such as lesion volume, percent spared in gray and white matter regions, diffusion-based fractional anisotropy and resting-state functional MRI (rs-fMRI) data. Our results show that combined behavioral, imaging and demographic models outperform single feature predictors. Functional connectivity at rest seems to be an important predictor of responsiveness to treatment, both alone and when combined with other patient-related data.

Predicting response to impairment-based aphasia therapy: Who doesn't respond?

Sigfus Kristinsson[1], Dirk den Ouden[1], Christopher Rorden[1], Argye Hillis[2], Leonardo Bonilha[3], Gregory Hickok[4], Julius Fridriksson[1]; [1]University of South Carolina, USA, [2]Johns Hopkins University, USA, [3]Medical University of South Carolina, USA, [4]University of California, Irvine, USA

The question of who responds to impairment-based aphasia therapy has garnered little attention in the aphasia therapy literature. This may, in part, stem from ethical concerns regarding how such research findings will affect clinical management of aphasia. Notwithstanding, identifying factors that dissociate between those who respond and do not respond to conventional impairment-based therapy may be a critical step toward developing more efficient therapy approaches for the latter group. Here, we used LASSO regression to classify 106 individuals with chronic aphasia as therapy (i) responders or (ii) nonresponders based on baseline lesion data, functional activity, resting-state, and structural connectivity measures acquired prior to six weeks of impairment-based aphasia therapy. The predictive value of each neuroimaging modality was examined separately, and model accuracy was statistically compared across prediction models. A multimodal prediction model combining all neuroimaging modalities together was subsequently developed. Our findings will be discussed with reference to ethical concerns.

Predicting individual responses to treatments for aphasia: one method to rule them all?

Thomas Hope[1], Ajay Halai[2], Matthew Lambon-Ralph[2], Jenny Crinion[1]; [1]University College London, UK, [2]University of Cambridge, UK

There is often significant inter-individual variance in studies of treatments for acquired language impairments (aphasia). If this variance can be predicted pre-treatment, the implication might be that we could target particular treatments to those patients most likely to benefit from them. Here, we use Partial Least Squares (PLS) regression models to predict individual responses to four different treatments (two for naming impairments, and one each for reading and comprehension impairments, respectively), in four independent samples of patients. Our approach appears effective in that it yields predictions that significantly out-perform a null model, which simply predicts the mean treatment response for every patient. Our predictions also significantly out-perform prior results for one of the four datasets (focused on reading impairment), found using step-wise feature selection and multiple linear regression. These results suggest that individual variance in many aphasia treatment studies might be systematic and predictable.

Wednesday, October 6, 8:30 - 10:30 am PDT   Join Zoom Webinar

Symposium 2 – Semantic knowledge representations in the anterior temporal lobes and beyond

Organizers: **Andrew Persichetti**[1] & **Alex Martin**[1]; [1]*Laboratory of Brain and Cognition, National Institute of Mental Health, NIH*

Presenters: Rebecca Jackson, Andrew S. Persichetti, Elizabeth Jefferies, Srikanth Damera, Stefano Anzellotti, Galit Yovel

A better understanding of how the brain represents diverse knowledge about the world (e.g., people, places, things, and relations between them) is critical to the study of human thought and language. There are two prevalent competing theories about how the brain represents semantic knowledge. One theory proposes that a single region in the anterior temporal lobes (ATL) integrates information from diverse sensory and category-selective systems to represent all semantic knowledge (i.e., a domain-general semantic hub). The other theory proposes that knowledge about categories is represented in segregated systems that represent category-specific knowledge (i.e., domain-specific systems). According to the latter view, the ATL is not a convergence zone for all semantic knowledge, but rather a collection of functionally diverse regions. In this symposium, we hope to spur a fun and informative discussion on this important question by presenting data from multiple theoretical perspectives and methodologies, including fMRI, EEG, and computational modeling.

Talks

Why do we need a multimodal semantic hub in ventral anterior temporal lobes?

Rebecca Jackson[1], Timothy T. Rogers[2], Matthew A. Lambon Ralph[1]; [1]MRC Cognition & Brain Sciences Unit, University of Cambridge, Cambridge, UK, [2]Department of Psychology, University of Wisconsin–Madison, Madison, WI, USA

There is convergent evidence for the role of the ATL in multimodal cross-category semantics from semantic dementia, PET, MEG, optimised fMRI techniques, TMS and intracortical electrodes. The temporal lobe forms a convergence zone with posterior regions showing differential involvement by sensory modality with a graded transition to multimodal representation of concepts in ventral aspects. Why is the temporal lobe organised in this way? By systematically varying the structure of a computational model and assessing the functional consequences, we identified the architectural properties that best promote core representation and control functions of the semantic system, which include a deep multimodal hub. Without a single multimodal hub, semantic systems do not acquire internal representations reflecting the full conceptual representational structure across modalities and learning episodes, with or without control requirements. The structural features promoting the functions of the semantic system mirrored the organisation of the temporal lobe; explaining its structure.

A data-driven functional mapping of the anterior temporal lobes

Andrew S. Persichetti[1], Joseph M. Denning[1], Stephen J. Gotts[1], Alex Martin[1]; [1]Section on Cognitive Neuropsychology, Laboratory of Brain & Cognition, NIMH/NIH, Bethesda, Maryland, USA

The functional role of the anterior temporal lobes (ATL) is a contentious issue. While different regions within the ATL likely subserve unique cognitive functions, most studies revert to vaguely referring to particular functional regions as “the ATL” and, thus, the mapping of function to anatomy remains unclear. Using a rigorous resting-state fMRI parcellation approach, we found that the ATL comprises 34 distinct functional parcels that are organized into a three-level functional hierarchy. In addition, the anterior region of the fusiform gyrus, often cited as the location of the semantic hub, was found to be part of a domain-specific network associated with social processing, rather than a domain-general hub. These findings are inconsistent with a brain region that subserves a singular cognitive function, such as a domain-general semantic hub, and highlight the importance of adopting more precise methods and language when studying functional divisions within the ATL.

Context Free and Context-Dependent Conceptual Representation in the Temporal Lobes

Elizabeth Jefferies[1], Zhiyao Gao[1], Li Zheng[2], André Gouws[1], Katya Krieger-Redwood[1], Xiuyu Wang[1], Dominika Varga[3], Jonathan Smallwood[4]; [1]Department of Psychology, University of York, Heslington, York, United Kingdom, [2]Department of Psychology, University of Arizona, Tucson, AZ, USA, [3]School of Psychology, University of Sussex, Brighton, United Kingdom, [4]Department of Psychology, Queen’s University, Kingston, ON, Canada

How does conceptual representation in the brain change according to the context? In an fMRI study, we varied the strength of thematic associations between words, from very strong (dog with leash), through intermediate trials (dog with beach), to unrelated items. We combined representational pattern similarity analysis and computational linguistics to probe the neurocomputational content of these trials. In ATL, individual word meaning was maintained when items were judged to be unrelated, but not when a linking context was retrieved. In contrast, context-dependent meaning was represented in left IFG and other sites associated with semantic control. These brain regions showed a dissociation in the effect of associative strength: ATL supported context-dependent meanings to a greater extent for strong associations; in contrast, IFG supported combined meanings even when more control was required. We suggest that ATL amplifies long-term semantic associations during retrieval but does not directly capture short-term non-dominant associations.

Evidence for Multiple Fast Feedforward Hierarchies of Concept Processing in the Human Brain

Srikanth Damera[1]; [1]Department of Neuroscience, Georgetown University Medical Center, Washington, DC, USA

The anterior temporal lobe (ATL) has been proposed to act as an amodal concept hub that is connected to distributed modality-specific concept representations. However, the extent to which the ATL is needed to coordinate and integrate information across these distributed representations is unclear. To better understand the dynamics of how the brain extracts meaning from sensory stimuli, we conducted a

human high-density EEG study in which we first trained participants to associate pseudowords with various animal and tool concepts. After training, multivariate pattern classification of EEG signals in sensor and source space revealed the representation of both animal and tool concepts in the left ATL and tool concepts within the left IPL within 250ms. We then used Granger Causality analyses to show that orthography-selective sensors directly modulated activity in the parietal-tool selective cluster. Together, our results provide evidence that communication between domain-specific representations can happen independent of the ATL.

Multivariate analysis of the interactions between brain regions reveals category integration in the angular gyrus

Stefano Anzellotti[1]; [1]Department of Psychology and Neuroscience, Boston College, Chestnut Hill, MA, USA

Representing the semantic relationships between objects from different categories is essential for human cognition. However, object representations are largely organized into distinct category-selective regions. How are different category-selective representations integrated? Previous research identified angular gyrus, anterior temporal lobe (ATL), posterior cingulate and medial prefrontal cortex as candidate regions for the representation of semantic knowledge. We used MultiVariate Pattern Dependence (MVPD) to test whether responses in these regions are better predicted by response patterns across multiple category-selective regions combined than by individual category-selective regions in isolation, finding evidence for category integration in the angular gyrus. We did not find significant category integration effects in the ATL, but this may be due to methodological limitations.

The contribution of perceptual and conceptual information to recognition memory

Galit Yovel[1], Adva Shoham[1]; [1]School of Psychological Sciences & Sagol School of Neuroscience, Tel Aviv University, Israel

Recognition memory benefits from conceptual encoding. This effect, which was originally reported for words, was extended to visual stimuli, showing better recognition following conceptual than perceptual encoding. But what is the nature of the representation that underlies this improved recognition? Two hypotheses were proposed to account for this effect: according to the feature elaboration hypothesis conceptual encoding enhances the perceptual representation. According to the conceptual representation hypothesis, conceptual encoding converts percepts to meaningful concepts. To decide between the two hypotheses, we examined the fMRI response during a recognition task to faces that were encoded conceptually/socially vs. perceptually. Results show that socially learned faces engage the anterior temporal (ATL) face area and the social brain network. Perceptual face regions showed no difference between socially and perceptually encoded faces. These findings support the conceptual rather than the feature-elaboration hypothesis, highlighting the importance of conceptual processing mechanisms for recognition memory of visual categories.

Friday, October 8, 6:00 - 8:00 am PDT Join Zoom Webinar

Symposium 3 – What can NLP systems teach us about language in the brain?

Organizer: **Mariya Toneva**[1,2,3]; [1]*Carnegie Mellon University*, [2]*Postdoctoral Fellow, Princeton University*, [3]*Assistant Professor, Max Planck Institute for Software Systems*
Presenters: **Evelina Fedorenko**, **Jixing Li**, **Jean-Rémi King**, **Leila Wehbe**, **Alexander Huth**

In the last few years, new computational tools have emerged for natural language processing (NLP) that significantly outperform previous methods across linguistic tasks, ranging from predicting upcoming words to answering comprehension questions. In particular, these methods learn to represent individual words and to flexibly combine these representations to account for the surrounding context and the task at hand, without enforcing specific constraints from linguistics. Recent work in neurolinguistics shows that these models can also predict brain activity during language comprehension to an impressive degree. How these new methods can improve our understanding of the neurobiology of language remains an open question. In this symposium, the speakers will discuss their perspective on the benefits and limitations of utilizing recent NLP systems for improved understanding of language in the brain. Our target audience is researchers who want to make scientific inferences about the neurobiology of language using powerful but complex computational methods.

Talks

The neural architecture of language: Integrative modeling converges on predictive processing

Evelina Fedorenko[1]; [1]Associate Professor, MIT

Recent advances in machine learning have produced artificial neural networks (ANNs) that achieve remarkable performance on diverse language tasks, providing the first computationally precise models of how language might work in the brain. We have begun to investigate whether state-of-the-art ANN language models capture human brain activity in the language-selective network. Adapting a pipeline developed in vision, we tested 43 language models on several neural datasets (fMRI+ECoG) and found that the ‘transformer’ ANN models accurately predict neural responses, in some cases achieving near-perfect predictivity. Critically, model-to-brain fit correlates with model performance on the next-word prediction task, but not other language tasks, suggesting that optimizing for predictive representations may be a critical shared feature of biological and artificial neural networks for language. We are now investigating the most brain-like models in richer detail to isolate the key contributors to model-to-brain fit and to develop intuitive theories around their inner workings.

Cortical processing of pronoun resolution revealed by computational models

Jixing Li[1]; [1]Postdoctoral Researcher, New York University Abu Dhabi

Human language processing involves not only combining word meanings in accordance with semantic and syntactic constraints, but also figuring out who and what is being referred to. Here we present the first study towards a mechanistic understanding of the neural basis for referential processing. Using both fMRI and MEG, we identified a consistent increase of activity in a network spanning the anterior and posterior left middle temporal gyrus and the angular gyrus for pronoun processing during naturalistic listening for both English and Chinese speakers. We then leveraged computational models to examine the cognitive processes underlying pronoun resolution. We evaluated the neural fit of three symbolic models that each formalizes a different explanation for pronoun resolution in the cognitive and linguistic literature, as well as two neural network models with different architectures. Our results favor the memory-based symbolic model, suggesting a domain-general mechanism of pronoun resolution that resembles memory retrieval.

When, where and why do deep nets learn to process language like the brain?

Jean-Rémi King[1,2]; [1]Researcher, CNRS, [2]École normale supérieure

Do deep learning models learn to process language similarly to humans, and is this similarity driven by specific principles? Here, we test whether the activations of artificial neural networks trained on (1) image/sound, (2) word and (3) sentence processing linearly map onto human brain responses to written words, as recorded with magneto-encephalography (MEG, n=204), functional Magnetic Resonance Imaging (fMRI, n=589), and intracranial electrodes (n=176 patients, 20K electrodes). Our results reveal that visual (or sound), word and language algorithms respectively correlate with distinct areas and dynamics of the left-lateralized cortical hierarchy of reading (or speech processing, respectively). However, only specific subsets of these algorithms converge towards brain-like representations during their training. Overall, these results reveal the structural and training principles that lead deep nets to converge to brain-like computations.

Testing neurobiology of language theories in the wild with natural language processing

Leila Wehbe[1]; [1]Assistant Professor, Carnegie Mellon University

Do findings about the brain obtained from controlled language tasks also apply when processing natural language that is not constrained into clean categories? Naturalistic experiments, by using complex language stimuli, allow us to study language processes in the wild, and to test if theories built on controlled stimuli generalize to the natural setting. To analyse these complex experiments, natural language processing offers powerful tools that can be carefully combined to create in vitro, post-hoc, computationally-controlled experiments. These computationally-controlled experiments can test targeted hypotheses and break the tie between different theoretical models of language processing. To make these generalizability tests accessible, we have built BOLDpredictions, an online tool for simulating fMRI experiments and testing the generalizability of findings from controlled experiments to the natural setting.

Interpretable multi-timescale models for predicting fMRI responses to continuous natural speech

Alexander Huth[1]; [1]Assistant Professor, University of Texas at Austin

Natural language contains information at multiple timescales. To understand how the human brain represents this information, one approach is to build encoding models that predict fMRI responses to natural language using representations extracted from neural network language models (LMs). However, these LM-derived representations do not explicitly separate information at different timescales, making it difficult to interpret the encoding models. In this work we construct interpretable multi-timescale representations by forcing individual units in an LSTM LM to integrate information over specific temporal scales. This allows us to explicitly and directly map the timescale of information encoded by each individual fMRI voxel. This approach outperforms other encoding models, particularly for voxels that represent long-timescale information. It also provides a finer-grained map of timescale information in the human language pathway. This serves as a framework for future work investigating temporal hierarchies across artificial and biological language systems.

Slide Session A

Comparing the Brain-Behavior Relationship in Acute and Chronic Stroke Aphasia

Natalie Hetherington[1], Argye, E. Hillis[2], Lisa Bunker[2], Roger Newman-Norlund[1], Chris Rorden[1], Leo Bonilha[3], Erin Meier[2,4], Emily Goldberg[2,5], Gregory S. Hickok[6], Gregori Yourganov[7], Julius Fridriksson[1]; [1]University of South Carolina, [2]Johns Hopkins University, [3]Medical University of South Carolina, [4]Northeastern University, [5]University of Pittsburgh, [6]University of California Irvine, [7]Clemson University

It is widely accepted that the lesion is among the strongest predictors of stroke aphasia severity. This appears to hold true in both acute and chronic recovery. However, there are arguments for using data from acute patients over chronic, and vice versa. Aphasia severity is often thought to be more stable in the chronic phase, and therefore may be the optimal time to investigate these relationships. Conversely, others argue that therapy and recovery-related morphological changes influence chronic behavior, therefore the acute stage is more appropriate. Despite this, to our knowledge there are no comprehensive studies that provide strong evidence in favor of one or the other. To that end, we investigated two aims; (1) whether the relationship between lesion load and behavioral impairment is similar in acute and chronic patients, and (2) if model based on acute data accurately estimates chronic data, and vice versa. Lesions and WAB-AQ scores from acute (N=63) and chronic (N=109) left hemisphere stroke survivors with aphasia were entered into separate univariate voxel-based lesion-symptom mapping (VLSM) analyses using the NiiStat toolbox for Matlab (https://www.nitrc.org/projects/niistat/). A support vector regression (SVR) model was trained on lesion data (proportion of ROI damage) from either the acute or chronic dataset; the coefficients were calculated for each region, as well as a constant term so that a sum of weighted percent damage for all regions plus the offset, gives an estimate of WAB-AQ. Predictions of WAB-AQ score were computed using linear-kernel SVR. Four analyses were conducted: 1) Trained on acute data, leave-one-out prediction of behavior 2) Trained on chronic data, leave-one-out prediction of behavior 3) Trained on acute data, predicting chronic behavior 4) Trained on chronic data, predicting acute behavior VLSM analyses revealed that similar, but not identical, regions in the acute and chronic samples were predictive of WAB-AQ. In both datasets, lesions in the superior temporal gyrus (STG), posterior STG, STG pole, middle temporal gyrus (MTG), posterior MTG, inferior temporal gyrus, inferior and middle occipital gyri, angular gyrus, superior longitudinal fasciculus, supramarginal gyrus, pre- and postcentral gyri, and the corona radiata were significantly associated with reduced WAB-AQ scores. A further 19 regions were predictors in the chronic dataset. Positive correlations were found between actual and predicted WAB-AQ scores: predicting acute using leave-one-out ($r = .7221$, $p < 0.001$), chronic using leave-one-out ($r = .5205$, $p < 0.001$), training on chronic, predicting acute ($r = .5568$, $p < 0.001$), and training on acute, predicting chronic ($r = .7220$, $p < 0.001$). Our findings suggest that brain-behavior relationships in both stages of stroke are comparable, and that data acquired at one timepoint may be used to estimate the other. This has important implications for clinicians, as it suggests that models based on acute data may also give us good insight into behavior in the chronic stage. Differences between critical brain regions in acute and chronic patients may give us further understanding into recovery patterns and/or regions likely to have further degeneration, however this should be tested more formally with longitudinal studies.

Finding the right connections: Investigating how tractography algorithms influence observed patterns of brain-language relationships

Maria Ivanova[1], Francois Rheault[2], Nina Dronkers[1,3]; [1]University of California, Berkeley, California, USA, [2]Vanderbilt University, Nashville, USA, [3]University of California, Davis, California, USA

Significant discrepancies exist across diffusion MRI studies regarding the contributions made by major fiber pathways, particularly as they relate to language pathology (Ivanova et al., in press; Vaidya et al., 2019). Here we investigate the method-specific impact of different tractography algorithms on observed patterns of tract-behavior associations and present a new approach for evaluating the role of different tracts in language processing. By simultaneously investigating four different iterative tractography algorithms and analytically combining their results, we provide a more definitive answer on the differential role that white matter pathways play in language processing. We investigated language abilities in 33 individuals with post-stroke aphasia using the Western Aphasia Battery (Kertezs, 2007). Structural and diffusion-weighted MRIs (64 directions, 2mm isovoxel, b=2000s/mm2) were performed on a Siemens Verio 3T scanner. The diffusion MRI data processing was done with the tractoflow pipeline, local models, i.e., tensor and fiber orientation distribution function (fODF), the tractography as well as the automatic bundle segmentation using Recobundles with multiple execution followed by labels fusion was performed using the Dipy library (Garyfallidis et al., 2014). We explored the following tractography algorithms: (1) single-peak tractography based on the tensor; (2) multi-peaks eudx tractography based on the fODF; (3) deterministic, and (4) probabilistic tractography based on the fODF. For each tracking algorithm main associative fibers (ILF, IFOF, UF, FAT and 3 segments of the AF) were automatically segmented from the whole brain tractogram in both hemispheres. As expected, discrepancies between the four algorithms were readily observed on tract reconstructions and occurrence heatmaps. Tensor-based tractography provided the smallest sized tracts and probabilistic tractography led to the largest reconstructions, with tracts generated with eudx and deterministic tractography falling in between. Then the volume of each bundle normalized by the hemisphere volume and mean fractional anisotropy (FA) values obtained for each tracking algorithm were correlated with language measures while accounting for lesion volume. Some tract-language associations were highly method-specific (observed only for 1 -2 algorithms), while a select number of patterns were all significant, irrespective of the tracking method employed. Next, these significant correlations were combined to determine which were observed systematically across the different algorithms, with correlations appearing in at least 3 out of 4 methods deemed reliable and amenable to further interpretation. Accordingly, the AF posterior branch was critical for naming and repetition, and the ILF for naming. FA analyses confirmed and expanded these findings, additionally implicating the IFOF and the long branch of the AF stemming from the middle temporal gyrus in lexical-semantic processing, and the anterior branch of the AF in spontaneous speech. The current study highlights method-specific variability in the establishment of tract-behavior relationships. The proposed multi-method approach helps to robustly outline the crucial language connections that need to be represented in future models of language processing and further explored as predictors of clinical outcomes. The proposed method of analysis is highly replicable and reliable. It should be used in future studies to minimize the impact of algorithm-specific artifacts and help to solidify and verify detected brain-language relationships.

Leukoaraiosis is not associated with recovery from aphasia in the first year after stroke

Alexandra C. Brito[1], Deborah F. Levy[1], Sarah M. Schneck[1], Jillian L. Entrup[1], Caitlin Onuscheck[1], Marianne Casilio[1], Larry Davis[1], Stephen M. Wilson[1]; [1]Vanderbilt University Medical Center

Individuals with post-stroke aphasia often recover language function over time. This recovery is thought to be driven by neural plasticity, which may be related to the health of surviving brain regions. Brain health is associated with observable changes on neuroimaging, including atrophy and leukoaraiosis (small-vessel cerebrovascular disease that appears as white matter hyperintensities on MRI) [1]. Prior work has suggested that leukoaraiosis severity may be a clinically relevant predictor of recovery from aphasia after stroke [2-4], although findings have been inconsistent [5]. This study investigates the relationship between leukoaraiosis and language recovery as measured by repeated aphasia assessments during the first year after stroke. In the context of a larger project on the neural correlates of recovery from aphasia in the first year after stroke, we recruited 269 patients with left-hemispheric stroke and coincident MRI (237 ischemic, 32 hemorrhagic; age: 63.0 ± 14.2 years). Leukoaraiosis was evaluated based on Fluid-Attenuated Inversion Recovery (FLAIR) images using the Fazekas visual rating scale [6], which ranges from 0 (absent) to 6 (most severe). Patients were evaluated for aphasia within 2–5 days of stroke using the Quick Aphasia Battery (QAB) [7]. For patients with acute aphasia (173 patients), follow-up aphasia assessments were performed at 1 month, 3 months, and 1 year following stroke, whenever possible. Multivariable regression models were fitted to the data to determine the relationships between leukoaraiosis and QAB scores at each time point, as well as changes in QAB scores over time. Covariates of age, sex, handedness, education, and stroke lesion extent were included in the models. We found that 90% of patients had some degree of leukoaraiosis. The mean score on the Fazekas scale was 2.7 ± 1.8 points. Leukoaraiosis severity was positively associated with age, female sex, and cerebrovascular risk factors such as hypertension and tobacco use. Multivariable regression analyses showed that leukoaraiosis did not predict initial QAB scores ($n = 269$, $t = –0.92$, $p = 0.36$), follow-up QAB scores at 1 month ($n = 80$, $t = 0.50$, $p = 0.62$), 3 months ($n = 77$, $t = 0.36$, $p = 0.72$), or 1 year ($n = 54$, $t = –0.35$, $p = 0.73$), or changes in QAB scores between any pairs of time points (all $p > 0.50$). In sum, we did not observe any relationships between leukoaraiosis severity and aphasia outcomes or change in language function over time. This negative finding contrasts with other domains such as cognition and motor control in which leukoaraiosis is predictive of deficits [8]. The lack of association between leukoaraiosis and language function may reflect the anatomical distribution of small-vessel cerebrovascular disease, which is largely medial and dorsal to critical language tracts. [1] Smith. Stroke 2010;41:S139–43. [2] Wright et al. Neurology 2018;91:e526–32. [3] Basilakos et al. Neurorehabil Neural Repair 2019;33:718–29. [4] Varkanitsa et al. Neurorehabil Neural Repair 2020;34:945–53. [5] Hatier et al. Ann Phys Rehabil Med 2019;61:e48. [6] Fazekas et al. AJR Am J Roentgenol 1987;149:351–6. [7] Wilson et al. PLoS One 2018;13:e0192773. [8] Longstreth et al. Stroke 1996;27:1274–82.

Acute white matter damage predicts connected speech recovery after stroke

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Introduction: Left hemisphere (LH) stroke impacts connected speech to different degrees but the neural predictors of differential recovery from the acute stage of stroke are unknown. Damage to disparate brain regions and their connections impairs connected speech (Alyahya et al., 2020) and white-matter tracts' acute damage has been found associated with the recovery of naming ability (Hillis et al., 2018). To examine the role of white-matter tract integrity in connected speech recovery, we assessed changes in lexical-syntactic aspects of connected speech during the first year after acute LH stroke while measuring the extent of acute lesions on white-matter tracts. Methods: We tested 41 individuals with LH stroke from the acute (within an average 4-days post-stroke) to subacute (2-mo, n=32) and chronic stages of stroke (6-mo, n=31; 12-mo, n=25). We elicited connected speech using story-telling and quantified speech using quantitative production analysis (Rochon et al., 2000). Following Ding et al. (2020), we extracted four connected speech components, including fluency, syntax, lexical selection and structural complexity. At the group level, acute and follow-up component scores were compared using paired t-tests. At the individual level, impairment was defined as below -1.67 S.D. of 13 age-and education-matched controls. Acute white-matter tract damage was calculated by the intersection between patients' lesion masks and the Rojkova et al. (2015) white-matter atlas. Dorsal tracts included anterior, long and posterior segments of the arcuate fasciculus (AF) and the frontal aslant tract (FAT). Ventral tracts included inferior frontal-occipital, inferior longitudinal and uncinate fasciculi (UF). We conducted a lesion-symptom mapping analysis to determine the difference in recovery (follow-up – acute) between tract-damaged and -preserved groups (lesion > 100mm3) while controlling for lesion volume and acute performance. Results: Behavior. At the group level, fluency improved significantly by the subacute stage ($p<0.02$). Syntactic ability marginally improved by 6-mo ($p=0.08$). Lexical selection significantly improved after 12-mo ($p=0.01$). No significant improvement occurred for structural complexity (p's>0.46). At the individual level across time points, the ratio of patients who recovered to within control performance from impaired acute performance for syntax was above 80%, but less so for fluency (50%-61%). Ratios for lexical selection and structural complexity were 67% subacutely and reached above 80% post 12-mo. Acute white matter tract damage. Subacutely, acute FAT damage related with diminished recovery of fluency and syntax (p's<0.03). Damage to UF marginally related with diminished recovery of lexical selection ($p=0.07$). Chronically, acute FAT damage related with diminished recovery of structural complexity (p's<0.006). Damage to long and posterior segments of AF related with diminished recovery of syntax at 6- and 12-mo (p's<0.01), respectively. Summary: Connected speech showed different degrees of recovery across follow-up stages where fluency recovered first but only half of patients recovered to within control performance, while syntax and lexical selection recovered later, but most participants recovered to control performance levels by 12-mo. Acute white-matter damage predicted connected speech recovery after stroke where dorsal pathway damage related to reduced recovery of fluency, syntax and structural complexity, while damage to ventral pathways reduced lexical selection recovery.

Slide Session B

Visualizing lexical activation during speech production

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Lexical retrieval is central to language, but the spatial and temporal neural codes that subserve it remain underspecified and elusive. Here we employ direct neural recordings (ECoG) in humans and leverage a machine learning (decoding) approach to elucidate the neural instantiations of two central aspects of lexical retrieval during overt language production: First, the spatiotemporal patterns of neural activity that code for a word's activation. Second, the neural states that correspond to discrete stages of lexical representation (conceptual, phonological, articulatory; Levelt, 1989; Indefrey, 2011). Four patients undergoing neurosurgery for refractory epilepsy repeatedly produced 6 nouns (dog, ninja, etc.) in response to cartoon images while electrical potentials were measured directly from cortex. During a picture naming block, patients saw an image of a cartoon character and responded overtly ("dog"). Subsequently, cartoon images of the same characters embedded in static scenes were shown while the patients produced corresponding sentences (e.g. "The dog tickled the ninja"). We were able to predict above chance ($p<0.05$, permutation, accuracy ~=22%) which of the 6 nouns a subject was about to produce in the ~500ms leading to articulation using cross-validated multi-class classifiers. Accuracy increased leading up to production onset and then decreased, suggesting that the classifiers are capturing a neural process akin to lexical activation rather than signatures of articulatory processing (or early visual features which were removed from analysis). We tested the generalizability of the finding by applying the same trained classifier to nouns produced in sentences, showing above-chance accuracy for the first noun in the sentence. Next, in order to test for discrete neural stages corresponding to lexical processes we employed a temporal generalizability approach where we trained classifiers on each time sample, and then tested each of these on held out trials from each time sample (following King & Dehaene, 2014; Gwilliams et al., 2020). If lexical activation involves passing through discrete representational stages which are instantiated neurally, the temporal generalizability pattern should show distinct temporal patches representing neural states. Our results provide direct evidence for 2-4 distinct neural states during lexical retrieval within subjects. These states commenced approximately 600 ms prior to articulation and continued until articulation onset. The neural states likely represent temporally stable patterns supporting conceptual, phonological, and articulatory planning processes. Our results provide an important step towards linking neural spatiotemporal codes to theoretical lexical states.

An ERP study comparing iconicity effects on translation and picture-naming tasks: Are effects of iconicity in ASL task-specific?

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Iconicity refers to the presence of a structured mapping between form and meaning in a word or sign. Growing evidence suggests that iconicity plays a role in lexical access and/or the production of signs in American Sign Language (ASL). Iconic signs are produced more quickly than non-iconic signs in picture-naming paradigms. The present study explores the effects of iconicity on sign production through the use of both a picture-naming and an English-ASL translation paradigm. As the past studies exploring the effect of iconicity on sign production have used picture stimuli, it is difficult to determine whether the facilitation found in these studies is driven by the overlap between visual features in the picture and the visual phonological features of the sign, thereby allowing the pictures to prime sign production. Through our inclusion of an English-ASL translation task, we hope to determine whether the same faciliatory effect is found for sign production regardless of whether pictures are being named, or English words are being translated into ASL. Deaf ASL signers either translated or named 88 items: 44 with iconic signs, and 44 with non-iconic signs. The order of the items in each block was counterbalanced across participants, but all participants completed the translation block prior to the picture-naming block to avoid recalling the picture during the translation task. EEG was recorded, and Event-Related Potentials (ERPs) were time-locked to word or picture onset and averaged offline. We investigated whether iconicity modulated the N400 component, a negative going component that peaks around 400ms after stimulus onset. Larger N400 components are associated with increased semantic processing, whether due to semantic incongruity or due to an increase in the number of semantic features activated and processed. Our prior picture-naming study found an increased N400 amplitude and reduced response latencies for iconic compared to non-iconic signs (McGarry et al., 2020). We hypothesize that this result reflects a more robust semantic network for iconic signs and is akin to the larger N400 amplitude observed for concrete words. If the present study replicates this more robust N400 activation for iconic signs in the translation condition, this would indicate that iconic signs are associated with greater activation of features/semantic networks than non-iconic signs, regardless of task. If the N400 effect is exclusive to picture-naming, this will instead suggest that the increased N400 amplitude is related to visual priming from the picture and is task-specific. While data collection and analysis are currently underway, our preliminary results suggest that there is indeed increased N400 activation and reduced response latency in the translation condition for iconic ASL signs compared to non-iconic signs, suggesting a more robust semantic network for iconic signs.

Decoding Typing from Electro-Encephalography Reveals how the Human Brain Simultaneously Represents Successive Keystrokes

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The neural bases of language production are difficult to study because mouthing generates muscular artefacts that disrupt neuronal recordings. To bypass this issue, we investigate language production through typing. Like speech, keystrokes are produced through sequences of precise and overlearned movements stemming from high level linguistic representations. Critically, however, typing movements are performed away from the brain and hence are not expected to perturb the recording of brain activity. To investigate how linguistic representations are translated into successive keystrokes, we aimed to decode individual keystrokes from electrophysiological (EEG) recordings acquired during a picture typing task. We re-analysed the data of a previous study (Pinet et al., 2016) in which 31 participants performed a picture naming task through typing. We implemented multivariate pattern analyses to decode the hand laterality and the finger corresponding to each keystroke as a function of time. Our results show that laterality can be significantly decoded up to 500ms before each keystroke onset, irrespective of the position of the keystroke in the word. Finger decoding, based on a standard finger-key correspondence, yielded qualitatively similar but much lower decoding performances. Most notably, the decodable time courses of individual keystrokes systematically overlapped with one another. Finally, to identify the spatio-temporal dynamics of these EEG representations, we implemented temporal generalization analyses by training a decoder at each time sample to test how well they decode other time samples. The results show that each keystroke is characterized by a diagonal pattern, meaning that its activation is stronger around the time of the keystroke but not across the full word. This implies that the neural representation of each keystroke is dynamic. We discuss how these novel EEG findings reveal the simultaneous representation of successive keystrokes in large-scale neuronal activity. More generally, we show that, similarly to the representation of language comprehension, the representation of language production can be decoded as multiple and rapidly evolving neural codes.

Functional brain networks associated with discourse ability in aging brain: A resting-state fMRI study

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Introduction: Discourse-related language function is thought to be impaired in neurodegenerative disease like dementia or with mild cognitive impairment (MCI). However, little is known about the functional brain networks supporting discourse-related language processing in healthy aging populations. From first principles, it makes sense that brain activity measured during rest, a state which is highly likely to include some generation of internal dialogue, may provide insight into one's ability to overtly produce narrative discourse. In this study, we evaluate the relationship between resting-state functional connectivity (rsFC) in core/extended language areas and performance on a narrative discourse task (Cat Rescue) in a group of healthy older adults. Methods: Sixty participants (M = 66.78, SD = 6.98) were recruited as part of the Aging Brain Cohort Study at the University of South Carolina (ABC@UofSC). Participants completed a narrative discourse task in which participants tell a story with a beginning, middle and end based on a complex visual scene. We calculated each participant's fluency factor (maze index) and semantic factor (based on percent noun, verbs, and pronoun index) scores. Each participant underwent a single, 12-minute eyes-closed resting-state fMRI (rsfMRI) scan. Preprocessing of rsfMRI data was done with SPM12 and involved default preprocessing steps specified by the CONN toolbox. Following image preprocessing and denoising, ROI-to-ROI connectivity (RRC) matrices based on the Harvard-Oxford Atlas were created for each participant. Finally, a univariate general linear model (GLM) analysis was applied to identify significant relationships (FDR-corrected $p < 0.05$) between discourse measures and rsFC. Results: Our analysis revealed that rsFC of several cortical regions in both the right hemisphere (RH) and the left hemisphere (LH) was significantly correlated with semantic factor scores. In particular, increased connectivity between right Heschl's gyrus (HG) and left posterior middle temporal gyrus (pMTG), left posterior supramarginal gyrus (pSMG), left and right temporal pole (TP) and left posterior temporal fusiform cortex (pTFusC) was associated with higher semantic factor scores. Functional connectivity between left Heschl's Gyrus and anterior MTG (aMTG) in the right hemisphere was also positively correlated with semantic factor scores. Whole-brain analysis revealed patterns of functional connectivity outside the core language network that were related to semantic factor scores including: connectivity between the left supplementary motor area (SMA) and right MTG, left precentral gyrus (PreCG) and right pTFusC and right PreCG and left pSMG. Discussion: Our data provide evidence that discourse ability (indexed by semantic factor scores) is related to specific patterns of rsFC in both the core and extended language networks. Specifically, discourse quality appears to depend on the strength of interhemispheric connections involving Heschl's gyrus and areas involved in lexical-semantic processing (pMTG, TP, aMTG) and phonology (pSMG), as well as connectivity of regions involved in motor aspects of speech production (SMA, PreCG). Given the demonstrated utility of discourse in predicting impending cognitive decline, it is critical that researchers better understand specific brain networks involved in, and predictive of, discourse generation.

Slide Session C

Neural pattern changes underlie successful sound-to-category mapping

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Learning to map multi-dimensional, continuous acoustic signals to discrete categories is fundamental to auditory perception. Successful sound-to-category mapping requires the brain to efficiently reorganize during learning to encode novel categories and guide categorization decisions. Previous studies (e.g., Feng et al., 2019, 2021) have demonstrated that inferior frontal and superior temporal regions within the core auditory system play important roles in representing newly acquired speech and auditory categories. However, it is not yet clear how the auditory neural system changes in real-time associating with successfully sound-to-category mapping during online learning. Here we conducted a functional magnetic resonance imaging (fMRI) experiment with a feedback-based sound-to-category training paradigm. We leveraged multivoxel pattern analysis to examine the extent to which changes in sound-related neural activation patterns during learning are associated with ultimate learning success. This design and analysis enable us to reveal the dynamic neural changes during the learning process (as compared to the pre-and-post training designs). Two groups of participants (N = 60) learned to categorize 40 ripple sounds into four categories but differing category structures with trial-by-trial corrective feedback in six training blocks (240 training trials in total). One group of participants learned rule-based (RB) categories, hypothesized to involve an explicit sound-to-rule mapping network while the other group of participants learned information integration (II) based categories, involving a procedural-based sound-to-reward mapping network. We estimated activation patterns of each sound in each block and calculated the neural pattern dissimilarities (NPDs) between each pair of blocks and sounds to represent changes in neural patterns from block to block. These NPDs were then correlated with a dissimilarity matrix derived from the learning outcomes (i.e., post-training accuracies) of the sounds. This outcome dissimilarity matrix reflects variabilities in successfully mapping a sound into a category. Significant correlations between NPDs and the learning outcome matrix suggest a close relationship between neural pattern changes and sound-to-category learning success during learning. We employed a searchlight approach to identify brain regions that show such a relationship. The searchlight-based neural-behavioral correlation analysis revealed positive correlations between neural pattern changes and learning outcomes for both II and RB learners in a distributed frontoparietal network, including the left middle frontal gyrus (MFG), left inferior parietal lobe (IPL), bilateral inferior frontal gyrus (IFG), bilateral precuneus, and bilateral medial prefrontal cortex (mPFC), which suggests that greater neural pattern changes during learning in this frontoparietal network is associated with more successful mapping. We did not identify any regions that show significant negative correlations. We did not find any regions that showed significant differences in correlation between II and RB learners, which suggests that the neural pattern changes in the frontoparietal network may be a category-general neural mechanism underlying sound-to-category learning success. These findings demonstrate a novel neural plasticity mechanism during the online learning process where updates or changes in neural activation patterns in the frontoparietal network support online sound-to-category mapping.

Timing embodied semantics, across and within the brain: A combined EEG/iEEG study on face-related nouns

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During semantic processing, the brain recruits multimodal conceptual systems and embodied mechanisms grounding modality-specific information. Yet, no consensus exists on how crucial the latter are for the inception of semantic distinctions, mainly because most research, focused on action-related words, has been undermined by varied motor artifacts. Here we combined EEG and iEEG to examine when nouns denoting facial body parts (FBPs) and non-facial body parts (nFBPs) are discriminated and individually classified in face-processing and multimodal networks. In two experiments, participants completed a semantic decision task involving 21 FBP nouns (e.g., nose) and 21 nFBPs (e.g., chest), marched for nine psycholinguistic variables and presented amid diverse filler items. The EEG experiment involved 25 young healthy participants. Signals were recorded online with a 128-channel system. ERP analysis of face-sensitive N170 modulations focused on two temporo-occipital four-electrode regions of interest, via Monte Carlo permutation tests (1000 permutations) combined with bootstrapping ($p < .05$, FRD-corrected). The iEEG experiment comprised two young patients with intractable epilepsy undergoing intracranial monitoring. Both had electrodes were implanted in key hubs of the face-processing network (right fusiform, ventral/rostral lingual, and calcarine gyri) and a multimodal semantic network (angular and supramarginal gyri). Time-frequency charts were obtained to identify differential modulations between conditions in each network (across patients) for the 1-20 Hz frequency range, sensitive to both semantic and facial processing. Digitized signals were analyzed using a windowed Fourier transform. Significant power changes were analyzed across time against baseline values and between conditions with non-parametric bootstrap tests with 2000 permutations ($p < .05$, FRD-corrected). Multivariate pattern analyses, via support vector machines, were also used to examine the classification efficiency of signals from both patients related to FBP and nFBP words between 1 and 20 Hz, for each network separately. Finally, EEG task-related connectivity was examined in an early (0-200 ms) and a late (200-400 ms) window, considering all electrodes across the scalp, via a non-linear method called weighted Symbolic Mutual Information (wSMI). The same metric was used to calculated iEEG connectivity considering the same windows for each pair of electrodes within both networks for each patient separately. Results revealed four main patterns. First, relative to nFBP words, nouns denoting FBPs increased N170 amplitude (a key signature of early facial processing) over the right hemisphere. Second, iEEG-derived time-frequency patterns showed that FBP words triggered fast (~100 ms) activity boosts within the face-processing network, mirrored by later (~275 ms) effects in multimodal circuits. Third, iEEG recordings from the face-processing network allowed decoding ~80% of items within the first 200 ms, while classification based on multimodal-network activity only surpassed ~70% after 250 ms. Finally, EEG and iEEG connectivity between both networks proved greater in the early than the late window. Collectively, these findings indicate that semantic differentiations can spring via fast

sensorimotor reenactments and rapid interplays with cross-modal conceptual systems. Accordingly, they challenge views which reject an inceptive role of embodied mechanisms in semantic processing as well as those that reduce semantic processing exclusively to embodied reactivations.

Divide & Concur: A Predictive Coding Account of the N400 Event-Related Potential Component

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Predictive coding is a prominent theory of cortical function that is increasingly invoked to explain aspects of language processing. According to this theory, the brain infers high-level structure from low-level sensory data through iterative cycles of top-down prediction, bottom-up prediction error, and incremental belief updating. In language comprehension, the N400 response has often been linked to “prediction error”, but there has been no prior attempt to explicitly model this ERP component within a predictive coding framework. Here, we developed a computational model of word comprehension based on predictive coding principles. Our goal was to determine if the activation dynamics of this model could accurately reproduce the time-course of the N400 response and its sensitivity to a variety of lexical and contextual factors. Based on a modified interactive-activation architecture (Spratling, 2016), our model includes three hierarchical levels of linguistic representation: orthographic, lexical, and semantic, with distinct state units and error units at each level. On each iteration, state units at a given level predict states at the level below. Any mismatch between these predictions and the true state generates a prediction error (PE), which is passed up to “correct” the state that generated this incorrect prediction. Over time, errors are minimized as the model settles on a correct lexical and semantic state that can accurately explain the bottom-up orthographic input. We operationalized the N400 as the summed lexical and semantic PE produced by the model, averaged in a 10-iteration window around the error’s peak. Lexical Simulations: We selected 512 four-letter words that orthogonally varied in frequency, concreteness and orthographic neighborhood size (ON). Concreteness was implemented as the number of semantic features associated with each word (9 vs. 18). ON was measured as the mean Levenshtein-distance between each word and the 20 nearest neighbors in the model lexicon, and frequency was implemented by biasing the model’s feedback weights based on each word’s corpus frequency. Results: As expected, model PEs reproduced the characteristic rise-and-fall of the N400 response. Consistent with human ERP data, the lexico-semantic PE was enhanced for words with additional semantic features, words with more orthographic competitors, and words with lower frequencies. Contextual Simulations: To simulate the effects of prior linguistic context, we presented word-pairs that were either repetitions (LIME–LIME), semantic associates (SOUR–LIME) or unrelated (BANK–LIME). To simulate contextual predictability, the higher-level state units associated with each word were clamped to activations proportional to their predictability(i.e. cloze), before presenting any bottom-up input. Results: Similar to human readers, lexico-semantic PEs were attenuated by both word repetition and semantic priming. We also observed a graded reduction in PEs as a function of word predictability. Finally, this model also reproduced interactions between lexical and contextual factors, with smaller effects of frequency and concreteness for predictable words. Discussion: Together, these findings suggest that predictive coding can provide a parsimonious and biologically-motivated account of evoked neural activity during word comprehension. Moreover, this approach can potentially simulate behavioral responses, such as lexical decision times, and make novel empirical predictions for neuroimaging studies. References: Spratling, Cogn Proc, 2016

The Effect of Information Structure on Word Order Processing: An fMRI Study

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Many languages grammatically allow canonical and non-canonical word orders. Previous neurolinguistic studies have reported greater involvement of the left inferior frontal gyrus (IFG) in the processing of non-canonical word orders (e.g., object-subject-verb [OSV] in Japanese) than its canonical counterparts (e.g., SOV in Japanese) because of its demand for syntactic computation (Kinno et al., 2008). Some behavioral and ERP studies have found that discourse factors, such as information structure, partially attenuate the processing demand of non-canonical word orders (Kaiser & Trueswell, 2004; Yano & Koizumi, 2018). To clarify the precise neural mechanism underlying syntactic computation of non-canonical sentences with relevant contextual effects, we conducted an fMRI study on sentence processing by manipulating word order and information structure. In particular, we intended to identify neural networks sensitive to (i) syntactic structure, (ii) information structure, and (iii) their interaction. The participants were 37 healthy, right-handed, native Japanese speakers (mean age: 20.8±1.7, 16 females). A total of 480 pairs of Japanese sentences were adopted from our previous ERP studies. Each pair consisted of a prior sentence and a target sentence. Half of the target sentences employed a canonical word order (SOV), and the rest used a non-canonical word order (OSV). There were two types of target sentences: one in which the initial noun phrase (NP) refers to discourse-old information (i.e., the entity mentioned in the prior sentence) and the second NP refers to a discourse-new entity (the given-new order) and the other in which the new information comes first (the new-given order). By manipulating the word order (SO vs. OS) and information structure (given-new vs. new-given) of the target sentences, four conditions were created (SgivenOnew, SnewOgive, OgiveSnew, OnewSgive). During the fMRI scanning, the prior sentence was presented in its entirety, and each phrase of the target sentence was presented one by one. To check whether participants understood the sentences, comprehension questions were asked randomly at the end of half of the trials. We tested the main effect of the word order (OS vs. SO), the information-structure (new-given vs. given-new), and the interaction between these two factors. Statistical analyses were performed with SPM12 using a random-effects model (corrected to $p<0.05$ by cluster size). Three major findings emerged. First, analyses of the main effect of word order ([OnewSgive+OgivenSnew] > [SnewOgiven+SgivenOnew]) revealed significantly greater activation in the left opercular part of the IFG (BA44), left premotor areas (BA6), and left posterior part of the superior temporal gyrus. Second, irrespective of the type of word order, the new-given conditions [OnewSgive+SnewOgiven] elicited greater activation than the given-new conditions [OgivenSnew+SgivenOnew] in the bilateral inferior parietal lobules and left triangular part of the IFG (BA45). Third, although no significant interaction was observed, the OnewSgive condition elicited greater activation in the left opercular part of the IFG (BA44) compared to the other three conditions. Taken together, these findings indicate that the left opercular part of the IFG (BA44) has a vital role in integrating the demands of syntactic computation and information-structural compensation (cf. Van Leeuwen et al., 2014).

Friday, October 8, 8:30 - 10:00 am PDT Join Zoom Webinar

Slide Session D

Neural tracking of acoustic, lexical, and semantic information in attended and ignored speech

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When we listen to continuous speech, low-frequency electrophysiological brain responses phase-lock to the acoustic envelope. This so-called speech tracking is relatively lowered when attention is directed away or when the acoustic signal is degraded. Recently, demonstrations of such neural tracking mechanisms have been extended to non-acoustic, linguistic features (e.g., lexical segmentation at word onsets; word frequency; semantic dissimilarity). However, it is not clear how the tracking of linguistic features is affected by selective attention and acoustic degradation. Here, we employed electroencephalography (EEG) recordings from N = 22 participants who were presented with an acoustically degraded spoken-language track to one ear (using 8-band noise vocoding) and another, acoustically intact spoken-language track to the other ear. The task instruction to attend either to the left or right ear input varied on a trial-by-trial basis. Using linear regularised forward models in the EEG, we first estimated the temporal response function (TRF) to the acoustic envelope, word onsets, word frequency, and semantic dissimilarity (quantified as the Euclidian distance of vectors representing the meaning of the previous and current word). Second, to assess the encoding fidelity of acoustic and linguistic information, we quantified encoding accuracy by calculating the correlation of the actual EEG response with the EEG response reconstructed by the TRF model. We tested the additional value for encoding accuracy when individual linguistic features were added to the TRF model. At shorter latencies (< 300 ms), the acoustic-envelope tracking response was amplified for attended versus ignored speech. At longer latencies (> 300 ms), linguistic features elicited a pronounced tracking response with a negative deflection around 400 ms after word onset over parietal regions, similar to the N400. Notably, segmental information (i.e., word onsets) enhanced the encoding accuracy for attended speech irrespective of degradation. Word frequency enhanced the encoding accuracy only at longer latencies and only for attended intact speech. Semantic dissimilarity enhanced the encoding accuracy at longer latencies for attended speech, irrespective of degradation. The present results demonstrate that in addition to the acoustic envelope, the human brain tracks certain linguistic features of speech inside the focus of attention, primarily for intact but also for acoustically degraded speech. Outside the focus of attention, however, no statistically robust tracking of linguistic features was discernible in the present study. In sum, later neural speech tracking responses, which have proven difficult to model and to interpret in the literature, are interactively shaped by attention and linguistic information.

Neurochemical changes of healthy ageing on semantic representation

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There is now considerable convergent evidence from multiple methodologies and clinical studies that the human anterior temporal lobe (ATL) is a semantic representational hub. Previously, we demonstrated that the regional GABA concentration in the ATL predicts human semantic processing and GABAerigc action in the ATL is crucial to the neurobiological contribution of semantic representation in young individuals. It has been argued that age-related changes in the neurochemical properties of the GABAergic system may underlie cognitive decline in older adults. However, age-related neurochemical changes in the ATL semantic function is not clear. Here, we combined functional magnetic resonance imaging (fMRI) with resting-state magnetic resonance spectroscopy (MRS) to measure task-related BOLD signal changes and GABA levels in the left ATL and the vertex as a control region. Participants performed a semantic association task and a pattern matching task (control task) during fMRI. Data were collected from 23 young (aged 19-29 years old) and 28 older (aged 60-90 years old) healthy adults. Our results demonstrated that older as compared to younger adults exhibited a reduced GABA levels in the ATL, as well as a decreased semantic task performance (slower reaction time: RT). In older adults, task-induced regional activity in the ATL was decreased compared to young adults. Importantly, the degree of task-related BOLD signal changes in the ATL was associated with semantic task performance. Older adults with stronger regional ATL activity performed the semantic task better with faster RT. In addition, semantic control regions including the inferior frontal gyrus (IFG) and posterior middle temporal gyrus (pMTG) revealed the reduced task-induced regional activity in the older adults relative to the young adults. In order to evaluate a network-level changes in the older adults, we performed functional connectivity (FC) analysis between the key semantic regions. We found a reduced FC between the IFG and pMTG in the older adults compared to young adults. Importantly, the degree of FC between the semantic regions was associated with semantic task performance. Individuals with stronger ATL-interhemispheric connectivity and the IFG-pMTG connectivity performed the semantic task better (increased accuracy and faster RT). Our combined fMRI and MRS investigation demonstrated that age-related GABA changes in the ATL and neural changes in the semantic system are crucial to semantic task performance in healthy older adults. This study contributes to a comprehensive understanding of how age-related differences in neurochemical processes may underlie cognitive decline in semantic representation.

Narrative Event Segmentation in the Cortical Reservoir

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During continuous perception of movies or stories, awake humans display cortical activity patterns that reveal hierarchical segmentation of event structure. Sensory areas like auditory cortex display high frequency segmentation related to the stimulus, while semantic areas like posterior middle cortex display a lower frequency segmentation related to transitions between events (Baldassano et al. 2017). These hierarchical levels of segmentation are associated with different time constants for processing. Chien and Honey (2020) observed that when two groups of participants heard the same sentence in a narrative, preceded by different contexts, neural responses for the groups were initially different and then gradually aligned. The time constant for alignment followed the segmentation hierarchy: sensory cortices aligned most quickly, followed by mid-level regions, while some higher-order cortical regions took more than 10 seconds to align. These hierarchical segmentation phenomena can be considered in the context of processing related to comprehension. Uchida et al. (2021) recently described a model of discourse comprehension where word meanings are modeled by a language model pre-trained on a billion word corpus (Yamada et al 2020). During discourse comprehension, word meanings (Wikipedia2vec embeddings) are continuously integrated in a recurrent cortical network – the Narrative Integration Reservoir. The model demonstrates novel discourse and inference processing, in part because of two fundamental characteristics: real-world event semantics are represented in the word embeddings, and these are integrated in a reservoir network which has an inherent gradient of functional time constants due to the recurrent connections. Here we demonstrate how this model displays hierarchical narrative event segmentation properties. The reservoir produces activation patterns that are segmented by the HMM of Baldassano et al (2017) in a manner that is comparable to that of humans. Reservoir neurons can be partitioned into virtual cortical "areas" based on their distribution of time constants due to the network recurrence. Context construction displays a continuum of time constants across these areas, while context forgetting has a fixed time constant across these areas. Virtual areas formed by subgroups of reservoir neurons with faster time constants segmented with shorter events, while those with longer time constants preferred longer events. A linear integrator could produce similar results for segmentation, and context construction and forgetting, but did not reproduce the distribution of time constants in the cortical hierarchy. This neurocomputational recurrent neural network simulates narrative event processing as revealed by the fMRI event segmentation algorithm of Baldassano et al (2017), and provides a novel explanation of the asymmetry in narrative forgetting and construction observed by Chien and Honey (2020), and proposes a natural explanation for the cortical hierarchy of narrative event segmentation time constants. The model extends the characterization of online integration processes in discourse to more extended narrative, and demonstrates how reservoir computing provides a useful model of cortical processing of narrative structure. Research Supported by the Region Bourgogne-Franche-Comte ANER Robotself

Complementary hemispheric lateralization of language and social processing in the human brain

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Humans have a unique ability to use language for social communication. The neural architecture for language comprehension and production may have emerged in the brain areas that were originally involved in social cognition. Here we directly tested the fundamental link between language and social processing using functional MRI data from over 1000 human subjects. Cortical activations in language and social tasks showed a striking similarity with a complementary hemispheric lateralization; within core language areas, the activations were left-lateralized in the language task and right-lateralized in the social task. An opposite pattern was observed in a minority group of subjects who had strong language activations in the right hemisphere. The fine-grained organization of lateralization effects revealed interesting details. In many areas, distinct subregions showed lateralization for either language or social processing. However, in one area located in posterior superior temporal sulcus (STSp), these subregions highly overlapped, suggesting a competition between language and social processing for shared neural resources. Consistent with this topography, we found a correlation between the magnitude of language lateralization in left STSp and the magnitude of social lateralization in right STSp. The lateralization

effects in STSp and other core areas of lateral temporal cortex predicted performance in the language and social tasks. Outside the language network and within regions in prefrontal cortex, there was a left-hemisphere dominance for both language and social activations, perhaps indicating multimodal integration of social and communicative information. Our findings provide new insights about how the homotopic areas of two hemispheres are complementarily involved in language and social processing. Such complementary hemispheric lateralization might be impaired in autism spectrum disorder.

Tuesday, October 5, 12:30 - 3:00 pm PDT Join Zoom Webinar

Slide Slam Session A

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Secondary damage of the thalamus in post-stroke aphasia: a new player in language recovery outcome

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Background. Secondary damage refers to the damage of a non-lesioned cerebral area following the primary lesion of another remote but connected cerebral area. Secondary damage of the thalamus was reported between three and twelve months post-stroke [1,2]. However, whether it is present in post-stroke aphasia (PSA) and whether it impacts language recovery is still unknown. Research on thalamic deep brain stimulation [3] and thalamic stroke [4] has shown that the thalamus and thalamic nuclei (i.e. pulvinar, ventral anterior nucleus and ventral lateral nucleus) are involved in lexical access but not repetition. We thus hypothesized that PSA patients with a volume reduction in thalamus and thalamic nuclei of interest would show lower lexical access but not repetition skills. Methods. 15 PSA patients following an ischemic stroke in the territory of the left middle cerebral artery (7 women, 71 12 years) and 18 healthy controls (10 women, 64 16 years) were recruited. The volumes of the left thalamus and the three left thalamic nuclei of interest were measured at the subacute (10 days post-stroke) and chronic (6 months post-stroke) stages for PSA patients and at two timepoints, 6 months apart, for controls. Volume change was computed for each region of interest (i.e. Vreduction = Vsubacute – Vchronic), as well as scores for lexical access (i.e. orthographic fluency) and word repetition. Analyses of variance were used to compare the volume change in thalamus and thalamic nuclei between patients and controls. Then, a set of independent samples analyses was conducted to investigate the relationship between thalamic volume reduction and language performance in PSA patients. Analyses were corrected for multiple comparisons using a first discovery rate. Results. The volume of the thalamus significantly decreased in patients between the subacute and chronic stages compared to controls (F(1,30) = 15.307, p = .004, partial 2 = .338). It was also the case for the pulvinar (F(1,30) = .14,336 p = .001, partial 2 = .323), ventral anterior nucleus (F(1,30) = 15.978, p = .002, partial 2 = .348) and ventral lateral nucleus (F(1,30) = 19.462, p = .001, partial 2 = .393). Patients were then divided into two subgroups: patients who showed a thalamic volume reduction and those who did not. Congruent with our hypothesis, patients with a thalamic volume reduction performed more poorly on the orthographic fluency task (U = 52, p = .032) but not on the repetition task (U = 26, p = .867). Conclusion. This is the first report of secondary damage to the thalamus in patients with PSA. Furthermore, results show that this thalamic secondary damage is specifically linked to the outcome of lexical access at the chronic stage of the disease. These findings bring to light the role of the thalamus in the neurobiological mechanisms influencing language recovery outcome in PSA. [1] Baudat et al. (2020) Neuroradiology. [2] Haque et al. (2019) Front Neurol. [3] Hebb et al. (2013) Brain Lang. [4] de Witte et al. (2011) Cortex.

Topic Areas: Disorders: Acquired; Meaning: Lexical Semantics

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The roles of language and semantics in gesture imitation following left-hemisphere stroke

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Introduction: Dual-route models of reading and word repetition distinguish between a semantic route and a direct non-lexical route that bypasses semantics[1]. Semantic information often confers benefits, but individuals with damage to the semantic route can still accomplish many tasks by relying on the direct route[2]. Similarly, dual-route models of action distinguish between a semantic and a non-semantic visuo-motor route to execute gestures[3]. This has been tested by comparing meaningful versus meaningless gesture imitation[4]. However, it remains debated how this system responds to damaged semantic integrity or access (e.g., via lexical input)[5]. This is significant due to the common co-morbidity of apraxia, aphasia, and semantic impairments after left-hemisphere cerebrovascular accidents (LCVA) and the utility of gestures in language rehabilitation[6]. In this study, we investigated the role of semantics and language in gesture imitation for patients with LCVA and the brain regions associated with benefit of semantic and linguistic information in gesture imitation. Methods: Participants were 18 neurotypical controls and 42 adults with chronic LCVA. Patients were excluded for severe language comprehension impairments (<4 on WAB comprehension[7]), but were not otherwise selected for presence of aphasia, apraxia, or semantic impairment. Lesion analyses included a subset of 39 patients. Participants completed three gesture imitation tasks: (1) named meaningful, (2) unnamed meaningful, and (3) meaningless gestures. Named versus unnamed examined linguistic benefits, while unnamed versus meaningless examined semantic benefits. The outcome variable was hand posture (HP) accuracy, the most sensitive component of gesture imitation[8], which captures when the shape or movement trajectory of the hand and/or wrist is incorrect. Mixed-effects models examined group (controls vs patients) by task (named, unnamed, meaningless) interaction effects on HP accuracy, with random effects of subject and item. Support vector regression lesion-symptom mapping[9] identified lesions associated with reduced benefit of linguistic information (named residualized against unnamed) or semantic information (unnamed residualized against meaningless) on HP accuracy. Voxelwise statistical significance was determined using Monte Carlo permutation analyses (10,000 iterations, $p<0.05$, clusters with >500 contiguous voxels). Results: There was a group-by-task interaction for HP accuracy, where patients were less impaired for named ($\beta=1.25$, $p<0.001$) and unnamed ($\beta=1.05$, $p<0.001$) compared to meaningless gestures. Controls showed better accuracy for named compared to unnamed ($\beta=1.02$, $p=0.04$) or meaningless gestures ($\beta=1.39$, $p<0.001$). Lesions associated with reduced benefit of the linguistic label (named vs unnamed) included middle and posterior temporal regions, basal ganglia, and uncinate fasciculus. Lesions associated with reduced benefit of semantics (unnamed vs meaningless) included middle and inferior frontal gyrus and precentral regions. Conclusion: For controls, linguistic cues conferred additional benefit on gesture imitation beyond meaning, whereas for patients, meaningful gestures conferred a benefit but there was no additional benefit of linguistic cueing. These patterns parallel findings of the benefits of semantic versus linguistic cues for action naming in people with and without aphasia[10]. Reduced benefits of language and semantics were associated with distinct lesion sites, consistent with the roles of prefrontal regions in semantic retrieval/control[11] and ventral stream regions in comprehension[12]. Future work will examine cross-domain benefits of semantic information for LCVA patients.

Topic Areas: Disorders: Acquired; Signed Language and Gesture

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Morpho-syntactic processing in Primary Progressive Aphasia and stroke-induced aphasia: comparison of ERP response patterns

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Introduction. People with the agrammatic variant of Primary Progressive Aphasia (PPA-G) and people with stroke-induced agrammatic aphasia (StrAph) both present with nonfluent speech and morpho-syntactic impairments in the presence of spared semantic processing [1]. However, in PPA-G grammatical deficits gradually emerge over time due to neurodegenerative disease, but occur suddenly following a cerebrovascular lesion in StrAph. Only a few studies have directly compared language deficits in StrAph and PPA, and none have used on-line paradigms, which are more sensitive to detect language deficits [2]. In the present study, we compared on-line processing of subject-verb agreement violations in PPA-G and StrAph using ERP. Methods. Sixteen healthy (ages: 35-78 years), 7 StrAph, (ages: 26-72 years) and 10 PPA-G (ages: 52-76 years) participants completed a sentence acceptability judgment task while EEG was recorded from 32 scalp electrodes. Both patient groups presented with language impairments consistent with agrammatism, with StrAph showing an overall more severe language profile, reduced fluency, and greater impairment on offline measures of sentence processing than PPA-G. Study materials included sentences containing either a morpho-syntactic (subject-verb agreement, n=50) or a semantic (n=50) violation, as well as correct sentences (n=100). For each condition, mean EEG amplitude in pre-selected time windows was entered as a dependent variable in mixed-effects regression analyses, with sentence type (correct, violation) and electrode region (posterior left/right/midline, anterior left/right/midline) as fixed effects and participant as a random effect. Results. Morpho-syntactic violations elicited a significant, posteriorly-centered P600 in the group of healthy adults. Compared to the healthy controls, StrAph showed a delayed P600 with an anterior shift, while PPA-G showed no response to morpho-syntactic violations. Semantic violations elicited a significant, centro-parietally distributed N400 in all three participant groups. Conclusions. Results indicate that morpho-syntactic violations trigger processes of re-analysis/repair in healthy participants. While PPA-G participants fail to detect such violations, StrAph show successful detection but delayed re-analysis processes. The anterior shift of the P600 in StrAph replicates the findings of a previous study in older adults [3]. Although the relationship between ERP scalp distribution and underlying neural sources is extremely complex, this result suggests increased reliance on domain-general resources [4] supporting re-analysis processes. In PPA-G, recruitment of domain-general cognitive resources may be hindered due to the more widespread cognitive decline in this group (see [5]). Results also suggest that semantic processing is preserved in both patient groups, in line with previous studies [6]. Notably, no anterior shift of the N400 was observed in the StrAph group, suggesting that the abnormal P600 topography in this group does not simply reflect lesion-related shifts. References. [1] Thompson, C. K., & Mack, J. E. (2014). Aphasiology, 28, 1018-1037. [2] Barbieri, E., et al. (2021). Neuropsychologia, 151, 107728. [3] Kemmer, L., et al. (2004). Psychophysiology, 41(3), 372–384. [4] Fabiani, M., et al. (1998). Psychophysiology, 35(6), 698-708. [5] Silveri, M. C., et al. (2019). Cognitive and Behavioral Neurology, 32(4), 225-235. [6] Hurley, R. S., et al. (2009). Journal of Neuroscience, 29(50), 15762-15769.

Topic Areas: Disorders: Acquired; Syntax

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Online comprehension of verbal time reference in primary progressive aphasia: Evidence from eyetracking

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Introduction Primary progressive aphasia (PPA) is a degenerative disease affecting language while leaving other cognitive facilities relatively unscathed (Mesulam, Wieneke et al., 2012). The three major variants of the disease affect language in different ways. The agrammatic variant is associated with grammatical impairments; the logopenic variant with deficient word retrieval; and the semantic variant with impaired lexical-semantic representations. Here we investigate verbal time reference in PPA. Verbal time reference specifies the information about when an event happens/happened. For example, drinks and is drinking indicate events in the present, but drank and has drunk indicate events that happened in the past. Prior evidence from many languages suggest that reference to past events is more tightly linked to complex grammar than reference to present events, hence past reference is more difficult to comprehend and more vulnerable to impairment in people with agrammatic aphasia resulting from stroke (Bastiaanse et al., 2011). The present study examined verbal time reference in patients with PPA, with the expectation that those with the agrammatic variant would evince greater difficulty with past than present time reference, but that logopenic or semantic variants would not show this pattern due to the relative sparing of complex syntax in these PPA variants. Methods Participants completed a visual world eye-tracking task of sentence comprehension, which was analyzed for accuracy and eye movement patterns. The task comprised 20 action photos (e.g., drink), each in a past reference form ("drank" or "has drunk") or a present reference form ("drinks" or "is drinking"). Participants listened to a sentence as they viewed an array of two action photos – one with the action ongoing (present) and one with the action completed (past) and pointed to the matching picture. Results Results from the eye-tracking data indicate that all PPA groups fixated on the correct picture less than the healthy controls for past time reference. This pattern also was found for present time reference in the logopenic and semantic, but not the agrammatic, groups. The agrammatic group also showed delayed looks to the correct picture relative to healthy controls, but only for past time reference. These results are consistent with prior findings for agrammatic participants, and consistent with a grammatical deficit that impacts comprehension of past time reference. The results from the logopenic and semantic subgroups suggest a lexical deficit that affects verb comprehension, but not specifically comprehension of past time reference. Conclusions These data add to the growing body of knowledge concerning the nature of the language deficits across the three variants of PPA. Our study implicates that grammatical impairment in past time reference is an important feature for language assessment of PPA.

Topic Areas: Disorders: Acquired; Syntax

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Influence of item- and individual-level semantic and phonological characteristics on word production in individuals with aphasia

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INTRODUCTION: Lexical-semantic and phonological properties of words have been shown to influence naming and word learning in neurotypical individuals. While this has also been investigated in individuals with aphasia, further study is required given inconsistent results across studies and to determine the interaction of these variables with individual impairment profiles. This retrospective study examined whether naming accuracy was predicted by (1) stimulus-level psycholinguistic properties, and (2) the interaction between stimulus-level psycholinguistic properties and individual semantic and phonological skills. METHODS: Participants were 35 individuals with chronic post-stroke aphasia (mean WAB-R AQ 63.5). Assessments evaluated overall aphasia severity using the Western Aphasia Battery – Revised Aphasia Quotient (WAB-R AQ) (Kertesz, 2007); naming via a 180-item picture naming task; and individual impairment profiles via three semantic (e.g., verifying whether a superordinate category applies to a word) and three phonological (e.g., judging whether two words rhyme) processing tasks. A single accuracy score for each domain was generated by calculating the average accuracy of the three tasks in that domain. Nine psycholinguistic variables were selected based on prior literature. Given high correlations among these variables, a principal component analysis (PCA) was completed with the stimuli condensing these variables into three components that represented lexical-semantic (age of acquisition, lexical frequency, typicality, and semantic neighborhood density), phonological (phonological neighborhood density, length in syllables, and length in phonemes), and phonotactic (phonotactic probability of phonemes and biphones) properties. For both questions, mixed effects logistic regression was used to predict binary noun naming accuracy, with WAB-R AQ as a covariate and random intercepts for item and participant. For Question 1, the three stimulus-level PCA scores were predictors with item category as an additional covariate (Model 1). For Question 2, three models were constructed, with predictors being the interaction between individual semantic skills and stimulus-level lexical-semantic word properties (Model 2a), individual phonological skills and stimulus-level phonological word properties (Model 2b), or individual phonological skills and stimulus-level phonotactic word properties (Model 2c). RESULTS: For Question 1, both the stimulus-level phonological ($p<.05$) and lexical-semantic ($p<.05$) component scores were significant predictors of naming accuracy (less complex words showed higher accuracy) (Model 1). For Question 2, there was a significant interaction between individual semantic processing skills and the stimulus-level lexical-semantic component ($p<.05$) (Model 2a); namely, in individuals with more severe semantic processing impairment, lexical-semantic word properties had little influence on response accuracy. In contrast, in individuals with more mild semantic processing impairment, words with less complex lexical-semantic properties showed greater accuracy. The interaction was not significant between individual phonological processing skills and the stimulus-level phonological (Model 2b) or phonotactic (Model 2c) components. CONCLUSION: In brief, lexical-semantic and phonological properties of nouns influence naming accuracy in individuals with aphasia. For lexical-semantic word properties, this interacts with individual semantic processing skills, with individuals with stronger semantic skills showing greater response accuracy for words with less complex lexical-semantic properties. This work confirms the influence of multiple psycholinguistic factors on word production in individuals with aphasia and demonstrates an interplay between stimulus-level lexical-semantic word properties and individual semantic impairment.

Topic Areas: Language Production; Disorders: Acquired

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Using Baseline Task fMRI BOLD Activity to Predict Treatment Gains in Persons with Aphasia Undergoing Language Therapy

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Imaging is an increasingly popular tool to develop predictors of treatment outcomes in aphasia (Crosson et al., 2019). Structural imaging-based lesion-symptom mapping (LSM) is a widely-used approach for identifying predictors, but the lack of network information in LSM may omit the holistic details needed to create valid language-network prediction models. Instead, task-fMRI offers neurobiological inspection of lesion impact on the whole language network, simultaneously encoding both domain-general and domain-specific information. This study aims to develop multivariate and mass-univariate analysis on whole-brain task-fMRI to predict treatment outcomes in persons with aphasia (PWA) undergoing intention treatment (INT) that invokes both domain-specific and domain-general aspects of word retrieval using a left-hand circular motion when producing responses. Fourteen English-speaking PWA (>6 months post-stroke) underwent treatment focused on naming pictures and generating category exemplars. Participants were randomized into INT (N=7) or a control treatment (N=7) (Benjamin et al., 2014). Treatment gains were assessed by calculating change in performance on category exemplar generation (CEG) from baseline to 2-weeks post-treatment. Additionally, baseline task-fMRI images were acquired during a CEG task. Images were processed as described in (Krishnamurthy et al., 2021) to compute the z-transformed area-under-the-curve (ZAUC) of task activity for each voxel. Whole-brain ZAUC and CEG change scores for all 14 participants were entered into a mass-univariate or multivariate analysis to investigate which method may be more meaningful on network level data. Mass-univariate analysis involved voxel-wise linear regression between ZAUC and CEG change scores where each voxel is assumed as independent. Multivariate analysis involved sparse canonical correlation implemented in LESYMAP (Pustina et al., 2018), where all voxels are entered into the model simultaneously. All ROI clusters were corrected for multiple comparisons ($p<0.05$, cluster size=50). Significant gains in CEG were seen in 6/7 INT and 3/7 control participants (Benjamin et al., 2014). Significant task activity could be identified at the network level for each participant (Krishnamurthy et al., 2021). The mass-univariate brain-behavior analysis revealed domain-specific aspects of semantic processing, where greater ZAUC in the left middle temporal gyrus and fusiform gyrus predicted reduced gains in CEG (negative slope). The multivariate brain-behavior analysis was sensitive to domain-general functions, where greater ZAUC in the left precuneus of the default mode network and left superior parietal lobule involved in attention predicted more gains in CEG (positive slope). We have shown the feasibility of using whole-brain, network-level task-fMRI data to compute brain-behavior predictor models. Our preliminary results highlight the need for both mass-univariate and multivariate analysis on whole-brain data as each analysis provides unique neural correlates that are differentially sensitive to domain-specific and domain-general aspects of language processing. Importantly, approaches that allow identification of both domain-general and domain-specific biomarkers offer more precise prediction of language recovery, thus facilitating patient triaging and individualizing treatment planning. This proof of principle study may provide a platform for developing conceptual neurocognitive models that can describe language treatment-induced neuroplasticity in PWA undergoing various treatments. Future work will involve sensitizing the biomarkers to account for INT-specific treatment changes.

Topic Areas: Language Therapy; Computational Approaches

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Functional Cortical Reorganization Supporting Therapy-Induced Language Recovery in Chronic Aphasia: A Large-Scale Clinical Trial

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Introduction The neural mechanisms supporting language reorganization following aphasia therapy remain elusive (e.g., Schevenels, Price, Zink, De Smedt, & Vandermosten, 2020; Wilson & Schneck, 2020). The lack of concrete evidence may, in part, stem from the fact that most prior studies have been grossly underpowered due to small sample sizes (all 32 studies in Schevenels et al.'s review included N < 30). Here, we compared competing hypotheses regarding the optimal functional reorganization supporting therapy-induced language recovery in aphasia by modeling therapy response based on baseline activity and activity changes in (a) left hemisphere language regions, (b) right hemisphere homologue regions, (c) bilateral domain-general regions, and (d) perilesional regions. Method A total of 93 patients with chronic aphasia (>12-months post-stroke) underwent baseline language assessments followed by 30-hours of anomia therapy (15 hours of semantic and phonological therapy in a cross-over design). Task-based functional magnetic resonance imaging (fMRI) was carried out at baseline and after language therapy. Participants were asked to name common noun pictures and to stay silent when presented with abstract images; functional activity specific to naming was obtained by contrasting naming-related activity and activity elicited by abstract image viewing. Therapy response was predicted from baseline functional activity and pre- to post-therapy activity changes in preselected regions-of-interest (Blank et al., 2014; Fridriksson et al., 2012; Fridriksson et al., 2016). The following factors were identified as independent predictors of therapy response and were therefore included as covariates in all prediction models: initial aphasia severity (Western Aphasia Battery-Revised Aphasia Quotient; Kertesz, 2007), participants' age at testing, presence/absence of diabetes, and lesion location. Results Overall therapy gain was most accurately predicted by baseline activity in right hemisphere language region homologs (R2 = 0.474, 95% CI: 0.231 – 0.697) and residual left hemisphere language regions (R2 = 0.476, 95% CI: 0.235 – 0.703). Activity changes in residual left hemisphere language regions (R2 = 0.427, 95% CI: 0.191 – 0.671) and right hemisphere homolog regions (R2 = 0.435, 95% CI: 0.194 – 0.683) similarly yielded accurate predictions of therapy response. Baseline activity in the right hemisphere angular gyrus (ß = 0.284) and left hemisphere posterior middle temporal gyrus (ß = 0.380), and activity changes in the left hemisphere insula (ß = -0.078) and right hemisphere posterior insula (ß = 0.511) emerged as the strongest predictors of therapy response in these models, respectively. Functional activity in domain-general and perilesional regions was not found to reliably predict therapy response in this cohort. Conclusion The current study represents the largest fMRI study of therapy-induced language recovery in aphasia to date. Our findings revealed that baseline activity in both left hemisphere language regions and contralateral regions in the right hemisphere predicts therapy response to a similar degree when variability explained by common behavioral variables and lesion damage is accounted for. Our findings emphasize the need to consider individual factors such as lesion size and location in relation to functional integrity to inform the neurobiological mechanisms of treated aphasia recovery. Future research should examine neural reorganization in subsamples guided by lesion characteristics.

Topic Areas: Language Therapy; Disorders: Acquired

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Resting-state functional connectivity following Phonological component analysis: the combined action of phonology and visual orthographic cues

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Anomia is the most frequent and pervasive symptom for people with aphasia (PWA). Amongst anomia therapy approaches, phonological component analysis (PCA) is a therapy incorporating phonological cues grounded on models of word processing attributing a key role to the phonological dimensions of noun retrieval. While PCA has been demonstrated effective in English [1, 2], the investigation of neural correlates supporting improvements following PCA remain scarce [2, 3]. Resting-state functional connectivity (rsFC) recovery as a marker of therapy-induced neuroplasticity (TINP)[4] has been previously reported by our team [5, 6]. The present study reports on the efficacy of PCA delivered in French and explores TINP using whole-brain rsFC. Ten PWA participated in a pre-/post-PCA fMRI study. Language and cognitive assessments were completed. A personalized set of stimuli was built based on the naming performance at baseline. PCA was delivered in French in a massed stimulation schedule - three one-hour sessions per week over five weeks - with the following procedure: PWA were asked to generate or choose explicit phonological cues after seeing a picture [1]. Phonological cues were written on the therapy board, as per original therapy design, to assist word retrieval. Wilcoxon signed rank test was performed on naming accuracy scores. fMRI data was preprocessed and analyzed using the CONN toolbox with SPM12. ROI-to-ROI rsFC was calculated as per 132 ROIs in the CONN atlas. PCA led to significant improvement with treated ($z=1.988$, $p=0.047$, $r=0.629$), and untreated ($z=2.807$, $p=0.005$, $r=0.908$) items. A pre-post comparison of rsFC patterns showed an increase in FC between the left anterior temporal fusiform cortex and left supracalcarin cortex (SCC) ($T=7.20$, pFDR-corrected=0.0053). Also, a decrease in FC between the right lingual gyrus and right superior frontal gyrus (SFG) was observed ($T=-5.73$, pFDR-corrected=0.0295). The results show that that PCA delivered in French improves word retrieval with treated and untreated words. As for rsFC changes following PCA, the evidence showed an increase in FC between the left anterior temporal fusiform cortex - involved in phonological representation of words in naming [7] and in reading [8], and in orthographic and phonological correspondence [9] - and the left SCC, i.e., the primary visual cortex. Furthermore, there was decrease of rsFC between the right lingual gyrus - involved in semantic and phonological in reading and character recognition [10],- and the right SFG, known for its role in organizing and enacting sequences of speech sounds [11]. As a whole, the rsFC changes can be interpreted within the frame of the visual-phonological nature of PCA. To conclude, behavioral and rsFC data changes associated with intensive administration of PCA to treat anomia in French, highlight the efficacy of PCA, and point to the importance of phonological-orthographic cues for the consolidation of a word-retrieval strategy that contributes to generalization of therapy effects to untreated words [12]. Future studies with a larger sample of participants are required to further explore this avenue. 1.doi.org/10.1080/02687030701831474 2.doi:10.3389/fneur.2018.00225 3.doi:10.1002/hbm.22448 4.doi:10.1016/j.bandc.2017.08.005 5.doi:10.1016/j.bandl.2012.11.004 6.doi:10.1016/j.bandc.2020.105659 7.doi:10.1006/brln.2001.2563 8.doi:10.1002/hbm.20122 9.doi:10.1093/cercor/bhw300 10.doi:10.1016/j.ijpsycho.2012.02.013 11.doi:10.1016/j.bandl.2011.05.010 12.doi:10.1080/02687038.2020.1781419

Topic Areas: Language Therapy; Disorders: Acquired

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Prediction of post-stroke aphasia treatment outcomes is significantly improved by inclusion of local resting-state fMRI measures

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Introduction: While the use of neural-based measures for predicting response to treatment in post-stroke aphasia (PSA) is of interest for basic science, its utility for clinical purposes is qualified by the relative difficulty and expense of collecting such measures. Recent work with rs-fMRI (e.g., Iorga et al., 2021; Demarco & Turkeltaub, 2020; Guo et al., 2019) indicates that local rs-fMRI analyses (as opposed to rs-fMRI connectivity based approaches) distinguish between healthy and lesioned tissues and index domain-specific language deficits. We investigated a set of local rs-fMRI measures in terms of their ability to contribute unique information for the purposes of predicting response to treatment, above and beyond what can be predicted on the basis of demographic or behavioral measures alone. Methods: 64 individuals with PSA subsequent to a single left-hemisphere stroke were treated for deficits in naming (n=28), spelling (n=22), or syntax (n=14), and completed rs-fMRI scans prior to beginning treatment. Response to treatment was measured as percentage of maximum gain from pre-to-post assessments on trained items. The rs-fMRI data were used to measure the fractional Amplitude of Low Frequency Fluctuations (fALFF; Zou et al., 2008) across the 96 anatomical gray-matter parcels of the Harvard-Oxford Atlas (Desikan et al, 2006). Four predictors were derived from the fALFF: with or without normalization within-participants, and with lesioned tissue excluded or assigned a value of 0. Response to treatment was first predicted, separately for each language domain, using the best set of demographic and behavioral measures (determined by exhaustive search through all variables, e.g., pre-treatment accuracy, age, sex) and prediction accuracy was assessed with cross-validation. The process was repeated including lesion volume and in turn each of the four fALFF predictors, with the best set predictors selected via elastic net regression (Zou & Hastie, 2005). The difference in the precision and 80% prediction intervals of the two sets of models (behavioral only versus behavioral and neural measures) were statistically assessed using Monte Carlo analysis. Results: Median absolute errors (MAEs) for predictions based on behavioral/demographic measures ranged from 11-17% across language domains. MAEs were significantly improved to 1-3% when including fALFF normalized within-participants (excluding lesioned tissue), for all three language domains. Similarly, 80% prediction intervals around the response to treatment narrowed from ±22-32% to ±4-6% (p's < 0.05), indicating the predictions were both more precise and expressed more certainty. The alternative neural measures (non-normalized FALFF or lesioned tissue expressed as fALFF = 0) did not significantly improve predictions of response to treatment beyond behavioral/demographic measures. Monte Carlo procedures demonstrated these improvements were not attributable to chance or "over-fitting" due to including additional predictors. Conclusions: These results are the first to statistically assess whether local rs-fMRI measures (fALFF) improve predictions of treatment outcomes in aphasia beyond demographic and behavioral measures. For the three language domains tested, normalized fALFF (excluding lesioned tissue) significantly improves precision and provides narrower prediction intervals over demographic and behavioral measures. We suggest this is the type of evaluation that should be applied in considering neural measures for clinical applications.

Topic Areas: Language Therapy; Disorders: Acquired

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Pre-treatment graph measures of resting-state functional connectivity predict language treatment outcome in aphasia

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Introduction: A great deal of variability exists in treatment-related behavioral outcomes in patients with post-stroke aphasia. In addition to known factors such as aphasia severity and lesion size and location, differences in the functional connectivity (FC) of intact brain regions are likely to play an important role. Graph measures of FC can be used to characterize properties of resting state networks. Integration and segregation measures have been found to be associated with behavioral deficits, but their relationship to treatment outcomes is not known. Here, we investigate this relationship and hypothesize that graph measures of FC in four functional networks, language (LN), default mode (DMN), dorsal attention (DAN), and salience (SN), predict treatment response in people with aphasia (PWA). Methods: Thirty chronic PWA (10F, time post stroke: mean=52 months, range=8–170 months) due to single left hemisphere stroke completed up to 12 weeks of semantic feature analysis treatment for word retrieval deficits. Mean baseline aphasia severity from the Western Aphasia Battery–Revised (WAB-AQ quotient) was 59.83 (range=11.7–95.2). T1-weighted anatomical scans and whole-brain resting-state fMRIs were collected at the baseline and preprocessed in FMRIPREP. Bivariate Pearson correlations between pairs of regions of interest (50 ROIs in total) were calculated in CONN. Patients' FC matrices were entered in BRAPH and converted to weighted, undirected graphs (one graph per network). We then calculated the weighted variants of three global graph measures (i.e., degree, global efficiency, clustering). The relationship between global graph measures of FC and treatment outcome was examined using mixed effects logistic regression. The models included treatment session and the graph measure of interest as predictors of accuracy on naming probes. WAB-AQ was also included as a covariate. Results: PWA with lower average degree ($p<0.001$) but higher global efficiency ($p<0.001$) and clustering ($p<0.001$) in LN showed greater improvement over time compared to those with higher average degree and lower global efficiency and clustering. In DMN, PWA with lower average degree ($p<0.001$) and global efficiency ($p<0.01$) showed greater improvement over time. PWA with higher global efficiency ($p<0.001$) and clustering ($p<0.001$) in DAN and higher average degree ($p<0.001$), global efficiency ($p<0.001$), and clustering ($p<0.001$) in SN showed greater improvement over time. Conclusion: In LN, lower average degree is associated with greater treatment response whereas higher global efficiency and clustering are associated with greater treatment response. One interpretation of these findings is that moderately high FC throughout LN, which would result in a high average degree, is not beneficial, but rather a more organized network in which a few connections are very strong while others are weaker is needed to maximize benefit from treatment. As for the non-language networks, our results suggest that greater integration and segregation in DAN and SN are associated with greater treatment response, whereas lower integration in DMN is associated with greater response. Overall, our results demonstrate that connectivity in both language and non-language networks is a good predictor of treatment response and provide support for a framework of language recovery that accounts for differences in network topology.

Topic Areas: Language Therapy; Disorders: Acquired

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Online spaced-repetition training for treating word-finding difficulties in aphasia

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Aphasia is a language processing deficit associated with left-hemisphere damage, which consistently results in an inability to produce known words. A common treatment approach is to repeatedly drill items in a picture-naming task. Although such training is relatively easy to administer and score, it is time-consuming and perhaps best suited for self-administration outside of therapy hours. Accordingly, efforts have been made to improve the efficiency of this type of training by making use of specific, item-scheduling strategies such as spaced-repetition, in which the time between presentations of the same item is manipulated. The purpose of the current study was two-fold. First, this study evaluated the potential utility of online picture-naming training performed without a therapist present. And second, the relative effectiveness of three unique spaced-repetition training schedules were contrasted both to each other, and to an untrained control condition. Twenty-two individuals, 18 of whom suffered from stroke-induced aphasia (four with primary progressive aphasia) were recruited. Each participant first completed a pretest over ZOOM in which 80 candidate pictures were selected for training from a pool of 292 pictures using a picture-naming task. The 80 pictures were then subdivided into four conditions, controlling for both word-frequency and the number of syllables. Sixty of the pictures (i.e., 3 conditions) were used in the training portion of the study, and the remaining twenty served as a control condition. The training portion of the study was conducted over two weeks for each participant. That is, each participant trained for 10-days (i.e., Monday-to-Friday). Each day, participants completed between 30 and 60 minutes of picture naming practice via an online learning portal. On each training trial, participants attempted to name a presented picture aloud, were given the answer, and self-scored. Each day, all three training conditions were practiced in a randomized order. The first training condition was a traditional, randomized “large-deck shuffling” of 20 items. The second training conditions was a “small-deck shuffling” approach (i.e., 5 items each, in 4 groupings) that resulted in a relatively closer average spacing of item repeats. And the third training condition was an adaptive algorithm, in which items correctly identified were repeated less frequently over time. Post-training teleconference evaluations were completed for all 80 selected pictures both at the end of the training period, and four weeks later. Performance was quantified on both response-accuracy and response-time. Overall, the training was successful at alleviating word-finding difficulties in the participants, with trained pictures showing higher accuracy and a faster verbal reaction time relative to the untrained control items. Also, the ‘small-deck’ condition under-performed on response accuracy relative to the two other training conditions (i.e., ‘big-deck’ and ‘adaptive’). Further, the ‘adaptive’ condition showed a modest decease in response-time, relative to the ‘big-deck’ condition overall. Thus, remote picture naming training is effective for treating word-finding difficulties in aphasia, and continued use of adaptive scheduling algorithms may maximize both response accuracy and efficiency.

Topic Areas: Language Therapy; Methods

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Phonological-component Analysis and aphasia recovery: a bilingual perspective

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Over the years, evidence shows bilingualism entails an advantage in cognitive performance, more so in ageing individuals(Ansaldo 2015, Berroir 2017, Dash 2019). Furthermore, there is evidence that the bilingual advantage on cognitive performance extends to persons with aphasia (PWA; Paplikar 2018, Ardila 2020), while better recovery in bilinguals PWA as compared to monolinguals has been also documented (Lahiri 2020). Few studies have examined the role of bilingualism on therapy-induced changes in naming performance. This work examines the effect of French-Phonological Component Analysis (Fr-PCA) in monolingual and bilingual PWA, while exploring pre- and post-therapy resting-state functional connectivity (rsFC) in each group, between the executive control network and the rest of the brain. Four monolingual (French) and four bilingual (French and English) PWA were included in this study. All participants received Fr-PCA (L1) anomia therapy for a total of 15 hours over 5 weeks on a personalized set of 20 items. Fr-PCA outcomes and rsFC measures were collected before and after therapy. Data was preprocessed and analyzed with the CONN toolbox (18.b;Whitfield-Gabrieli 2012) and SPM12. Three target seed regions supporting executive control (EC) were selected (Fan 2005), namely the right middle frontal gyrus (BA6) the inferior frontal gyrus (BA45), and the anterior cingulate cortex (BA32). We calculated rsFC between them and the 32 networks in the CONN toolbox (Whitfield-Gabrieli 2012). There was a significant improvement on treated words, and a generalization of Fr-PCA effects to untreated words. Improvement was also reflected by measures of connected speech (Richardson 2016) and executive control (Eriksen 1974) across groups. Importantly, as compared to monolinguals, bilingual PWA showed a larger effect size of therapy effects on naming both with treated and untreated items, and they were also more accurate than monolinguals on the Flanker task (Eriksen 1974). Regarding the rsFC pre-therapy, a positive correlation between the EC network and task-positive network of salience for monolingual PWA and frontoparietal (FPN) for bilingual PWA was observed. Post therapy, the bilingual PWA showed a positive correlation between the EC network and the default-mode network (DMN), and the EC network and the dorsal attention network (DAN). The results suggest a bilingual advantage in the recovery from aphasia following Fr-PCA as reflected by cooccurring behavioural improvements and changes in rsFC in the bilingual PWA. The pre-therapy rsFC results are discussed in terms of distinct connectivity pattern for the monolingual and bilingual PWA, where both the groups demonstrate positive connectivity between EC and task positive networks (Elton 2014). For the post-therapy rsFC, EC network in bilingual PWA correlated positively with the DAN as well as the DMN (Elton 2015) whereas in monolingual PWA, the EC network failed to correlate significantly with any other network. This study provides evidence for the role of bilingualism in aphasia recovery, while highlighting the impact of EC and attentional networks. These novel findings are limited to a small set of bilingual profiles and cannot be generalized on the continuum of bilingualism.

Topic Areas: Language Therapy; Multilingualism

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Indeterminate sentences in aphasia: investigating coercion and the nature of compositionality

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INTRODUCTION Sentences such as “Mary began the book” are called indeterminate because they do not make explicit what the subject (Mary) began doing with the object (the book). These types of sentences have generated much interest because they represent a case study for a central issue in language representation and processing: compositionality. Specifically, (1) Is semantic composition simple (classical) or is it enriched with intended or implicit constituents? And (2) what is the nature of the linguistic and cognitive resources involved in the interpretation of the event that the sentence conveys? There have been at least two proposals for how the meaning of an indeterminate sentence is attained. One assumes classical compositionality, with much of the interpretation of the sentence being the product of pragmatic inferences (e.g., Fodor & Lepore, 2001; de Almeida & Riven, 2021; de Almeida & Lepore, 2018) triggered by a syntactic gap ([began [v [the book]]; de Almeida & Dwivedi, 2008). An alternative view assumes that some form of local semantic enrichment takes place—often via what is called “coercion” or “type-shifting” (e.g., Pustejovsky, 1995, 2011; Asher, 2015). Coercion relies on internal analyses of the noun complement yielding an enriched form of compositionality (viz., [begin the book]→[begin reading the book]). Thus far, the only study investigating this phenomenon in aphasia supported semantic coercion based on greater difficulty by “Wernicke’s patients” in understanding indeterminate sentences (Piñango & Zurif, 2001). We investigated the coercion hypothesis in a group of 14 individuals with aphasia from different etiologies, and with lesions in either the left or right hemisphere. METHOD Our sample included 5 non-fluent [NF], 4 fluent [FL], 3 mixed but predominantly non-fluent [MN], 2 with mixed aphasia [MX], and 41 healthy controls. Participants completed a sentence-picture matching task whereby a sentence was aurally presented, immediately followed by two pictures on a computer screen. Their task was to choose the picture that best represented the sentence they heard. Sentences were: (a) indeterminate (The academic began the research), (b) fully determinate (“preferred”: …conducted the research), (c) figurative (viz., in need of pragmatic enrichment: …dumped the research), or (d) determined but non-preferred (…abandoned the research). Only one picture was the correct choice for indeterminate and fully determinate sentences. The competing picture was the correct choice for the figurative and non-preferred sentences. RESULTS Repeated-measures ANOVAs revealed a main effect of group, sentence type, and an interaction. Overall, group analyses showed that, when compared to controls, NF individuals had significantly more difficulty choosing the correct picture when presented with indeterminate sentences. Further, pairwise comparisons revealed that FL, NF, and MX individuals performed worse with indeterminate sentences than fully determinate sentences. Results from case-series analyses will be presented. DISCUSSION We propose that indeterminate sentences may be resolved by a syntactic-gap detection and by pragmatic inferences. We take the difficulty with indeterminate sentences shown by the NF group (compared to controls) to suggest that they have problems computing the syntactic gap that may serve to trigger a search for an appropriate event during semantic composition.

Topic Areas: Meaning: Combinatorial Semantics; Disorders: Acquired

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Influences on cognate facilitation in healthy bilinguals and bilinguals with aphasia

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Introduction: Cognates share a continuum of overlapping phonological and orthographic features between languages, resulting in a facilitatory effect during lexical access (Costa et al., 2000). In bilingual individuals, a spectrum of language experiences (e.g., use, age of acquisition) may influence the extent of facilitation between native (L1) and second language (L2; Rosselli et al., 2014). Aphasia, an access deficit, tests the resilience of the facilitation effect (Kohnert, 2004). We sought to examine and compare the factors influencing naming accuracy in L1 and L2 on English-Spanish cognates and noncognates in healthy bilinguals (HB) and bilinguals with aphasia (BWA) while examining the influence of language experience. Methods: Twenty-seven bilinguals with aphasia (mean age = 53, SD = 16.17, range = 21 – 82) and 31 healthy bilinguals (mean age = 43, SD = 15.34, range = 18 – 82) completed the Language Use Questionnaire (LUQ; Kiran et al., 2010) and Boston Naming Test (BNT) in English and Spanish. BWA also completed the Western Aphasia Battery-Revised (WAB-R) in both languages. In matching for item difficulty, 22 cognates and 22 noncognate pairs were selected from the BNT (Gollan et al., 2007). Cognateness was measured continuously by first computing and then taking the average of normalized Levenshtein distance ratings between written and phonetic transcriptions of the aforementioned word pairs. Principal component analyses (PCA) were performed on L1 and L2 LUQ scores from all 31 HB and from a larger set of 59 BWA; 27 BWA were included in this analysis. This resulted in Background, Use, and Environment components in both L1 and L2 across both groups. Individual-specific factor loadings were extracted from PCA results and used in regression analyses. Logistic mixed-effects models were fitted to examine the effect of cognateness and language experience in both L1 and L2. In BWA models, we included Aphasia Quotient (AQ) per WAB-R. For each group, four models were constructed, two in each language that examined either BNT item difficulty or lexical frequency. Results: In HB, cognateness is a significant predictor of naming accuracy in both languages across all models. In contrast, results in BWA suggest that cognateness is not a significant predictor of naming accuracy in either language when controlling for lexical frequency. Furthermore, naming accuracy in BWA is influenced by item difficulty and lexical frequency, Use in L1 and L2, and AQ in L1 and L2. Likewise, accuracy in HB is influenced by item difficulty and lexical frequency, language experience components in both languages (Use and Environment), and interactions between language and these components. Cognate advantage was stable between languages within groups but comparatively diminished in BWA: L1 in HB (0.25, d = 0.57); L2 in HB (0.26, d = 0.57), versus L1 in BWA (0.09, d = 0.19); L2 in BWA (0.08, d = 0.17). Summary: These results suggest that (i) quantified language experience is an informative predictor of naming in both healthy and disordered bilingual populations, and (ii) cognateness yields only minor benefits for bilingual individuals with aphasia, exhibiting minimal predictive power on naming accuracy.

Topic Areas: Multilingualism; Disorders: Acquired

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Clustering and switching in verbal fluency across different language contexts: Evidence from bilingual aphasia

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Introduction. Understanding levels of control during language production in bilingual persons with aphasia (BPWA) remains a highly complex topic. In bilingual speakers, we can operationalize two levels of control which are critical for successful language production. First, language control, manages interference from the non-target language across different interactional contexts, a factor which is modulated by relative proficiencies in each language. Second, semantic executive control directs activation and inhibition of lexical candidates in a contextually appropriate manner. These two levels work in conjunction to ensure effective communication for bilingual speakers. In BPWA, damage to the language system results in deficits in language production, however it is not yet well understood if these deficits arise, in part, from the level of language control, semantic executive control, or a combination of the two. Verbal fluency tasks provide a useful opportunity to examine these two levels of control in BPWA. Aims. Therefore, this research examined clustering and switching performance on semantic category generation and letter fluency tasks across four language conditions for thirty-five Spanish-English BPWA and twenty-two Spanish-English healthy bilinguals (HB). Here, clustering refers to successively producing lexical items belonging to a semantic subcategory, or with overlapping phonemic features, while switching is a transition from one cluster to another. Methods. All tasks were completed in the first- (L1) and second-acquired (L2) language as identified by a language use questionnaire (LUQ). The four language conditions implemented in the semantic category generation task consisted of two No-Switch (NS-L1 and NS-L2) conditions where participants responded in only their L1 or L2, one Self-Switch (SS) condition, where participants switched between languages as desired, and one Forced-Switch (FS), which required participants to switch between languages after each response. Participants also completed a traditional letter fluency task in each language (LF-L1 and LF-L2). Results. Overall, we found that HB outperformed BPWA across all measures, reflective of damage to the language system for BPWA. In the semantic category generation task, clustering performance did not differ across conditions, but both groups demonstrated superior switching performance in SS and NS-L1 compared to both NS-L2 ($p=.015$ for SS and $p=.001$ for NS-L1) and FS ($p=.002$ for SS and $p=.004$ for NS-L1). This suggests that increased control demands originating from the level of language control (i.e., switching between languages in a controlled manner in FS or inhibiting the prepotent language in NS-L2) impedes participants' ability to implement semantic executive control processes to systematically search within the lexicon, while automatic spreading activation engaged during clustering was not affected. In the letter fluency task, we found a significant Group × Condition interaction [$F(1, 54)=5.900$, $p=.019$] for clustering performance, indicating that HB produced larger cluster sizes in LF-L1 compared to LF-L2, but BPWA performed similarly across conditions, suggesting BPWA were sensitive to increased semantic executive control demands imposed by this task, resulting in reduced clustering performance in both languages. Conclusion. In sum, this study highlights that BPWA demonstrate semantic executive control deficits which are further impacted by increasing language control demands.

Topic Areas: Multilingualism; Language Production

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A study of syntactic acceptability judgments in chronic post-stroke aphasia using lesion-symptom mapping

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Prior lesion-symptom mapping studies have associated damage to posterior networks with syntactic comprehension deficits and paragrammatic speech. By contrast, lesion-symptom mapping studies have associated damage to frontal networks with agrammatic production deficits and to some extent, deficits in comprehension of complex non-canonical structures, but with little implication in basic syntactic comprehension deficits. However, most studies assess syntactic comprehension indirectly through the use of noncanonical sentence comprehension. Syntactic acceptability judgments (SAJ), which ask participants to gauge sentences' well-formedness, provide a more direct assessment of syntactic comprehension. We predicted people with aphasia (PWA) would better detect word-order violation than agreement or subcategorization violations. We expected lesion-symptom mapping to show association between comprehension deficits and damage to posterior temporal regions, but no association with frontal damage, consistent with Wilson & Saygin (2004). We adapted Wulfeck & Bates (1991)'s SAJ task into two experiments. We presented our experiment in 2 tasks, with 64 sentences each (eight of each type, examples below), suggesting English was the speaker's second language. In both tasks, we manipulated sentences' grammaticality, ½ ungrammatical, counterbalancing placement of the (single) error, on the object (examples a/c) or verb (examples b/d). Task 1 manipulated agreement (examples a/b) and word-order (examples c/d) grammaticality. (a)She is baking a cake/*a cakes. (b)She is/*are baking a cake. (c)They have listened to some teachers/*teachers some. (d)They have listened/*listened have to some teachers. Task 2 controlled whether verbal complements were obligatory (examples e/f) or optional (examples g/h), and manipulated subcategorization selection (e.g., auxiliary selection for verbs (examples e/g) or subordinate complement/adjunct selection by adding/deleting/substituting prepositions on prepositional or noun phrases (examples f/h)). (e)They are chasing a cat/*in a cat. (f)They have signaled/*have signaling to a boat. (g)He is answering a phone call/*to a phone call. (h)They are hurrying/*have hurrying to a meeting. From responses, we performed a repeated measures (RM) ANOVA to identify differential accuracy by error type and location, and regressed participants' lesions against error detection in both tasks using NiiStat, correlating lesion site to grammatical processing, following Matchin et al. (2020). Eighteen PWA participated. RM ANOVA results showed a significant main effects of error type ($p<.001$, $F(1.622)=3.195$, $\eta p2=.176$). Main effect of error location ($p=.054$, $F(1.000)= 4.358$, $\eta p2=.225$) and interaction between error type and location ($p=.068$, $F(1.264)= 16.345$, $\eta p2=.521$) were approaching significance. Predictably, participants were more accurate on word-order violations (M=65%), but unexpectedly more accurate on subcategorization violations (M=52%) than agreement violations (M=46%). Lesion-symptom mapping showed stronger associations to the posterior temporal ROI (agreement: $z=-.886$, $p=.188$; word-order: $z=-1.195$, $p=.116$; subcategorization: $z=-1.543$, $p=.061$) than the inferior frontal ROI (agreement: $z=-.675$, $p=.250$; word-order: $z=1.498$, $p=.933$; subcategorization: $z=-.581$, $p=.281$). Generally, word-order violations (66% correct) were easier to detect than agreement (49%) or subcategorization (50%) violations; violations showed association to posterior temporal regions rather than inferior frontal regions, consistent with findings by Wilson & Saygin, but contra suggestions that frontal regions primarily support grammatical comprehension processing. Differential accuracy across violation types could be because word-order involves sentence constraint, while agreement and subcategorization require processing hierarchical dependencies; further, agreement is an unbounded dependency.

Topic Areas: Syntax; Disorders: Acquired

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Grammatical parallelism in aphasia revisited: a common lesion substrate for syntactic production and comprehension deficits in the posterior temporal lobe

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INTRODUCTION A grammatical parallelism hypothesis in aphasia is commonly espoused: that agrammatism and syntactic comprehension deficits coincide, resulting from common injury to Broca's area and/or surrounding cortex (Caramazza & Zurif, 1976; Friederici, 2017; Thompson et al., 1997). However, Matchin & Hickok (2020) advocate an alternative hypothesis: that syntactic comprehension deficits coincide with paragrammatism, characterized by the use of complex constructions and functional elements, with syntactic errors rather than overall simplification or reduction (Goodglass, 1993; Kleist, 1914), resulting from common injury to the posterior temporal lobe. Here we test both parallelism hypotheses. ***METHODS*** 220 people with chronic post-stroke aphasia were assessed with the Western Aphasia Battery-Revised (Kertesz, 2007). Subjects' lesions were manually drawn on their MRI scans and warped to MNI space (Fridriksson et al., 2018).To assess syntactic comprehension, we combined the Sequential Commands subtest with the Auditory Word Recognition subtest as a covariate. Sequential Commands requires subjects to perform increasingly complex sequences of simple actions (e.g. point with the pen to the book), most of which require syntactic parsing to perform correctly. Auditory Word Recognition requires subjects to point to actual or drawn objects, pieces of furniture, shapes, letters, numbers, colors, and body parts (e.g. point to the cup). A subset of 53 subjects were previously assessed for grammatical production deficits using consensus perceptual ratings by four expert raters of elicited speech samples (Cinderella story protocol from AphasiaBank MacWhinney et al., 2011) (Matchin et al., 2020). Agrammatism and paragrammatism ratings were covaried with words per minute to control for speech rate. We first performed one-tailed non-parametric correlations between each grammatical production measure (incorporating lesion volume as a covariate) and the syntactic comprehension measure for the set of 53 subjects. For each of the 220 patients, we calculated proportion damage within each region of interest (ROI), defined as the lesion distributions associated with agrammatism and paragrammatism (voxel-wise $p < 0.01$), incorporating lesion volume as a covariate, created using NiiStat (https://www.nitrc.org/projects/niistat/). We then performed one-tailed non-parametric correlations between damage to each ROI and syntactic comprehension scores. ***RESULTS*** Agrammatism was not associated with lower syntactic comprehension, (Kendall's tau B = -0.063, $p = 0.255$, Figure 1, top left), but paragrammatism was significantly associated with lower syntactic comprehension (Kendall's tau B = -0.329, $p = 0.0002749$, Figure 1, top right). Damage to the agrammatism ROI was not associated with lower syntactic comprehension (Kendall's tau B = 0.009, $p = 0.577$, Figure 1, bottom left), but damage to the paragrammatism ROI was significantly associated with lower syntactic comprehension (Kendall's tau B = -0.134, $p = 0.002$, Figure 1, bottom right). Overlap analyses (including lesion volume, voxel-wise $p < 0.01$) showed almost no overlap in lesion distributions between agrammatism and syntactic comprehension, whereas there was significant overlap for paragrammatism and syntactic comprehension in posterior superior temporal gyrus and sulcus. ***CONCLUSIONS*** Our results speak against the grammatical parallelism hypothesis rooted in agrammatism and damage to the inferior frontal lobe, and in favor of the grammatical parallelism hypothesis rooted in paragrammatism and damage to the posterior temporal lobe.

Topic Areas: Syntax; Disorders: Acquired

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Longitudinal speech markers of motor and cognitive disease in ALS-FTD spectrum

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Introduction: Speech is controlled by motor processes associated with the planning and execution of articulators in producing utterances and cognitive processes of selecting and arranging appropriate vocabularies to convey a message. Clinical markers that are quantitative and domain-specific to individual-level changes are crucial for delivering targeting clinical care and to track therapeutic trial outcomes in conditions with mixed motor and cognitive disorders such as amyotrophic lateral sclerosis–frontotemporal dementia (ALS-FTD). Automated digitized speech measures can serve as inexpensive, non-invasive, and specific markers of disease. In this study, we analyzed longitudinal changes in speech acoustic and lexical-semantic measures in ALS-FTD using an objective and automated method. We hypothesized that cognitive and motor factors would show partially differential longitudinal changes in patients with ALS-FTD disorders. Methods: We analyzed digitized speech samples of Cookie Theft picture descriptions longitudinally from n=23 ALS-FTD patients over a course of 2-5 years (77% ALS, 23% ALS-FTD). The automatic speech analysis involved: (1) segmenting the acoustic signal into speech and silent pauses and pitch-tracking to extract duration measures and f0 range as properties of speech timing and prosody; (2) forced-aligning the transcript to the acoustic signal, tagging vowels based on established word pronunciation, and extracting vowel formants to derive measures of articulatory-acoustic working space and vowel-consonant transition speeds; and (3) tagging part-of-speech (POS) categories of tokenized words, and rating lexical-semantic characteristics to establish POS usage and lexical diversity. We examined within-individual changes and relations with clinical scales of cognitive (ECAS ALS Specific), bulbar motor (Penn UMN bulbar scores), and respiratory impairments (%FVC), and explored relations to MRI cortical thinning. Results: Articulatory rate (syllables/sec) ($p = 0.037$) and second formant transition slopes ($p = 0.041$) significantly declined over time in all patients, indicating neuromuscular slowing of tongue articulatory movements. f0 range interacted with bulbar scores covarying for cognitive scores ($p = 0.021$) showing that f0 range declined over time only in patients with bulbar disease after controlling for cognitive severity. Lexical-semantic measures interacted with cognitive scores after controlling for bulbar motor severity: reductions in average age of acquisition ($p = 0.004$), word ambiguity ($p = 0.050$), and word length (in number of phonemes) ($p = 0.020$), and an increase in word concreteness ($p = 0.012$) was observed only for patients with ALS-FTD. Summary: With the implementation of automated speech analysis methods, natural speech can provide independent markers of motor and cognitive disease in ALS-FTD. Our current report demonstrates the value of these digital speech markers in longitudinal patient follow-up.

Topic Areas: Speech Motor Control; Language Production

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Organizing Variables Affecting fMRI Estimates of Language Dominance in Patients with Brain Tumors

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While functional magnetic resonance (fMRI) has become a useful and widely used method to assess language dominance before brain surgery, the technique has limitations that need to be considered when interpreting its results. Numerous variables can affect the assessment of language dominance using pre-surgical fMRI in patients with brain tumors (Nadkarni et al. 2017, Batouli et al. 2016). This work (Połczyńska 2021) organizes the variables into two broad categories of confounding and modulating factors. Confounding factors give the appearance of changed language dominance. Most confounding factors are fMRI-specific, and the confounding factors would not distort other methods examining language dominance (e.g., the Wada test). The impact of confounding factors on the evaluation of fMRI language dominance can be substantial. There are tumor-related, and fMRI analysis confounds. The tumor-related confounds include tumor characteristics (tumor location, tumor grade, volume, and the age of onset) and tumor-induced conditions (aphasia, prior neurosurgery). The fMRI analysis confounds represent technical aspects of fMRI methods that can also disrupt the assessment of language dominance (e.g., a fixed versus an individual threshold, using a single task versus a panel of tasks, a whole-hemisphere versus a region of interest approach). Modulating factors can modify language dominance without confounding it. Modulating factors are not fMRI-specific, and they can impact language dominance both in healthy individuals and neurosurgical patients. The effect of most modulating factors on fMRI language dominance is suggested to be smaller than that of confounding factors. Modulating factors include demographics (age, sex, handedness), and linguistic factors (early bilingualism, sign language, and language characteristics, e.g., tones). Three retrospective cases of brain tumors in the language-dominant left hemisphere are presented to illustrate how the confounding and modulating factors can impact pre-surgical estimates of fMRI language dominance. The patients performed three fMRI language tasks: object naming, auditory responsive naming, and verbal responsive naming. An experienced neuropsychologist created language maps using minimal pre-processing. Task-related activations were identified through the application of a Pearson's Correlation Coefficient. An individual threshold was applied for each individual, and a conjunction of the language maps was performed. The approach has been demonstrated to be valid, systematic, and reliable (Benjamin et al. 2017). The first case was diagnosed with WHO grade IV glioblastoma in Broca's area. Signal loss in and around the lesion from prior resection was reported. The second case had grade III frontal glioblastoma in the left hemisphere. Despite a large tumor volume, she suffered from no language deficits. She displayed left hemisphere dominance with a bilateral representation of Broca's region. The third case was a left-handed, early Spanish-English bilingual with grade II anaplastic astrocytoma in the left parietal lobe. Spanish and English were left hemisphere dominant, with a bilateral organization of Broca's area in both languages and the basal temporal language area in Spanish. Intraoperative language mapping was conducted in all three patients. In sum, organizing the multiple variables into the two distinct categories can help interpret the results of pre-surgical language mapping with fMRI.

Topic Areas: Methods; Language Production

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Event associated experiential features are involved in event representation at brain regions preferentially representing event concepts

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Introduction: Investigation of concept representation in the brain has concentrated on object concepts, with far fewer studies of event concepts. A previous fMRI study [1] showed that event concepts engage left temporal-parietal areas more than object concepts, yet the mechanism underlying this preferential representation is unclear. Embodiment theories of concept representation claim that cortical regions involved in processing perception and action experiences also represent concepts. Here we investigate the hypothesis that differences between event and object concept representation in the brain reflect underlying differences in their experiential content. We used a previously validated 65-dimensional experiential model of conceptual content [2-3] together with representational similarity analysis (RSA) on a large fMRI dataset. Methods: 39 healthy adults each participated in 3 fMRI sessions, during which event and object nouns were presented visually in a jittered event-related design, and participants rated the familiarity of each word on a 1-3 scale. The stimuli included 40 items in each of 4 event categories (social, nonverbal sound, verbal sound, and negative events) and 4 object categories (animals, foods, tools, and vehicles). Each word appeared 6 times across the 3 sessions. Multivariable regression was used to generate a t map for each word. To define regions of interest (ROIs), whole-brain searchlight classifiers were applied separately to the 4 event and 4 object categories, and the event and object cross-validation classifier accuracy maps were contrasted. A 10-mm radius patch was placed around local peaks in each significant cluster to form ROIs. RSA multiple regression was then applied on all 320 words using the neural representational dissimilarity matrices (RDMs) from these ROIs as dependent variables and model RDMs representing experiential features in the conceptual model as independent variables. In addition, a categorical model coding the 8 categories was included to assess the alternative hypothesis that neural representation depends primarily on category membership. Single sample t-tests were applied to the regression coefficient of each experiential feature, which were thresholded using FDR at $\alpha < 0.05$. Results: Comparison of classifier accuracy maps yielded 13 ROIs where accuracy was higher for events compared to objects, located in left inferior frontal cortex, left superior temporal sulcus, left supramarginal gyrus, left medial prefrontal cortex, left posterior cingulate cortex, and right inferior frontal gyrus. Within these ROIs, the similarity structure of neural activations was correlated with model similarity structure mainly for features related to social (Social, Communication), spatial (Scene), causal (Caused, Consequential), temporal (Short), sound (Low), and motivation (Needs) experiential content. The categorical model was not significantly related to neural activation at any ROI. Discussion: Regions preferentially engaged by event concepts show sensitivity to experiential content that distinguishes events from objects. These results suggest that differences between event and object concept representations in the brain reflect underlying differences in their experiential content. References 1. Bedny, M., S. Dravida, and R. Saxe, Cogn Affect Behav Neurosci, 2014. 14(3): p. 891-901. 2. Binder, J.R., et al., Cogn Neuropsychol, 2016. 33(3-4): p. 130-74. 3. Fernandino, L., et al., bioRxiv, 2021: p. 2021.03.16.435524.

Topic Areas: Meaning: Lexical Semantics; Reading

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Neural activations during word reading versus story listening predict concurrent and longitudinal reading comprehension

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The Simple View of Reading (SVR) posits that word recognition (WR) and language comprehension (LC) abilities are predictors of reading comprehension (RC), together accounting for approximately 60% of the variance in RC scores. Despite these clear behavioral connections, the neural underpinnings of the SVR are not well understood. To elucidate these relationships, we assessed 29 typically developing children for their behavioral RC performance after first (M age = 7.6), second (M age = 8.5), and third (M age = 9.6) grades, and collected fMRI data at baseline. Children completed three task-based fMRI paradigms: (1) one WR task where they viewed short, scrambled phrases (e.g., “field the other”), and (2) two LC tasks where they listened to narrative and expository passages. Compared to rest, all functional tasks showed a variety of language area activity, including most notably overlapping bilateral superior temporal sulcus activity. To investigate how this brain activity predicted within-year RC performance and subsequent growth in RC, we correlated brain activity with first grade RC scores and change in RC scores from second to third grade (while controlling for first grade RC). First-grade behavioral RC was predicted by left angular gyrus activity during the WR task, and RC growth was predicted by left anterior temporal lobe activity during the LC tasks. Consistent with previous behavioral literature, these findings suggest that while the neural basis of early WR is more important for predicting early concurrent behavioral RC outcomes, neural activity associated with LC is more predictive of RC growth. Thus, these findings provide further insights into our understanding of the neural underpinnings of the relationship between word reading, language comprehension, and reading comprehension.

Topic Areas: Reading; Development

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Cortical Representations of Concrete and Abstract Concepts in Language Combine Visual and Linguistic Representations

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To process natural language, the human brain relies on semantic representations that store knowledge acquired through perception and language. Some previous neuroimaging studies have found that semantic representations reflect perceptual properties of concepts, while others have found that semantic representations reflect word associations learned from language. However, little is known about how perceptual and linguistic information are combined in each semantically selective cortical region, and whether different concepts are represented by different amounts of perceptual and linguistic information. To address these issues, we constructed computational models of how visual and linguistic information combine to form semantic representations. We modeled visual representations using image embeddings extracted from a convolutional neural network. A novel propagation method was used to model abstract words by combining image embeddings of associated concrete words. We modeled linguistic representations using distributional word embeddings that capture word co-occurrence statistics across a large corpus. We then combined the visual and linguistic embeddings for each word in different ratios to create semantic embedding spaces, which model different hypotheses for how visual and linguistic information are combined in the semantic system. We compared the different semantic embedding spaces to concept representations in each cortical region using a natural language fMRI experiment. Subjects listened to 5 hours of narrative stories from The Moth Radio Hour, and voxelwise encoding models were estimated to predict BOLD responses for each subject from the stimulus words. Comparing encoding model performance, we found that cortical regions near the visual system represent concepts by combining visual and linguistic information, while regions near the language system represent concepts using mostly linguistic information. Assessing individual concept representations near visual cortex, we found that more concrete concepts contain more visual information. Notably, however, we found that even many abstract concepts contain some amount of visual information from linguistically associated concrete concepts. Our results provide a computational account of how visual and linguistic information are combined to represent concrete and abstract semantic concepts across cortex.

Topic Areas: Meaning: Lexical Semantics; Computational Approaches

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The role of the medial parietal cortex in referring to common objects

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The ability to establish referential relations is a hallmark of language. While formal processes of semantic computation have received detailed theoretical treatment, the neural architecture for language composition remains less well understood. Here, we isolate the mapping of sentence representations onto successful versus unsuccessful referents. We used intracranial electrocorticography to address this issue, providing the most detailed, high spatiotemporal resolution neurobiological analyses to date of linguistic reference. Patients (n=56) implanted with either penetrating depth or surface grid electrodes (n=13,298) for the evaluation of medically refractory epilepsy were asked to quickly and accurately articulate the name of common objects in response to orthographic descriptions (average: 6.5 words, range: 3-12 words; average response time: 1385ms), presented in rapid serial visual presentation (500ms per word). The final word in each sentence was either referential to a lexical item, or non-referential (“A person at the circus who makes you [laugh/commute]”) (84 trials per condition). We analyzed broadband gamma (70–150Hz) activity at each electrode to index cognitive engagement. We found robust responses in medial parietal cortex, para-hippocampal cortex and lateral prefrontal cortex for the encoding of semantically coherent referential expressions. We identified greater gamma activity at the onset of the final word in referential trials across left inferior frontal regions (150ms post-onset), medial parietal cortex (250ms), para-hippocampal gyrus (400ms) and ventromedial prefrontal cortex (730ms). We also found greater gamma power for non-referential trials in pSTG, marking the violation effect. Medial parietal regions mediate action encoding, which possibly explains these effects, since non-referential items often involved impossible/failed actions (e.g. “Something that grows on your [face/name]”). These regions are also part of the default network, which shows activity increases during endogenous attentional tasks, with representational search likely being greater for referential relations. We also contrasted non-referential trials that were semantically coherent and contained only weak violations of lexico-semantic or syntactic rules (e.g., “Something you beat with grass”, which does not refer to a lexical item but which is still semantically coherent) with non-referential trials that contained strong violations (e.g., “A glass made of Wednesday”). We found increased gamma activity in anterior inferior frontal gyrus and posterior middle temporal gyrus for semantically coherent non-referential trials. This points to a role for these regions in in constructing semantically legal structures, which do not require ongoing lexical search but purely the evaluation of the read-out of semantic composition operations. Our intracranial analyses in a large patient cohort represent the first direct recordings of a central component of natural language semantics: reference to lexical concepts. Insight into this fronto-parietal referential network will contribute to rehabilitative solutions and neuro-prosthetic designs for individuals with reading deficits, and in particular patients with anomic aphasia and alexia.

Topic Areas: Meaning: Lexical Semantics; Meaning: Discourse and Pragmatics

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Low-Dimensional Structure in the Space of Language Representations is Reflected in Brain Responses

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There are a multitude of common techniques for analytically representing the information contained in natural language. Language representations can highlight specific linguistic properties, such as parts-of-speech or sentence chunks, or utilize well-known NLP models such as the intermediate layers of pretrained language models. In fields such as linguistics, natural language processing, and cognitive psychology, qualitative adjectives are often used to describe these language representations -- e.g. “low-level” or “high-level” and “syntactic” or “semantic”. The use of these words belies an unstated hypothesis about the nature of the space of language representations -- namely that this space is fundamentally low-dimensional, and therefore that the information from the representations in this space can be efficiently described using a few categorical descriptors. In this work, we attempt to directly map the low-dimensional space of language representations by generating “representation embeddings” using a method inspired by the work of Zamir et. al. This method uses the transfer properties between representations to map their relationships. Specifically, language representations are embedded based on how well the information contained in each representation can be used to regress to 100 prominent language representations from a large group. These representations include well-known word embedding spaces such as GloVe and FLAIR, as well as intermediate layers from common language models such as GPT-2, BERT, and Transformer-XL, and two machine translation models. Using these mapped 100-dimensional embeddings, we use multidimensional scaling to generate a low-dimensional structure. The principal dimension of this structure is especially interesting as it seems to capture an intuitive notion of a language representation hierarchy. Representations with negativelow values along the main dimension include word embeddings as well as the earliest layers of most of the language models and machine translation models, whereas higher valued representations with more positive values include the deeper layers of these models, as well as many interpretable syntactic and semantic representations. We show that mapping the principal dimension of the representation embeddings onto the brain recovers voxels that are thought to involve to higher-order, longer timescale language processing, such as those in prefrontal cortex and the precuneus. We also generate fMRI encoding models which try to predict BOLD response from a natural language stimulus represented by our 100 language representations. Using a discriminability metric, we show that representation embeddings can be correctly matched to their corresponding voxelwise encoding model performance maps over 90% of the time for all representations, and 100% of the time for the majority of representations. This suggests that the low-dimensional structure we generate is reflected in the hierarchy of linguistic representations in the brain.

Topic Areas: Computational Approaches; Meaning: Lexical Semantics

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fMRI activation patterns associated with linguistic vs. visual predictive cues in the visual-world paradigm

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Purpose. In the visual-world paradigm, participants listen to words or sentences and view visual stimulus arrays as their eye movements are tracked. This eye-tracking paradigm has been critical for understanding linguistic prediction. We used a novel task to identify fMRI activation patterns associated with prediction and subsequent processing of auditory words within the visual-world paradigm. Methods. 20 young adults participated in a combined event-related fMRI/eye-tracking experiment. In each trial, two pictures (a single object and a pair of identical objects) sequentially appeared and disappeared from rectangular boxes, followed by a cue as to which picture would re-appear in a box. In the “Language-Visual World (VW)” condition, the auditory linguistic cue (“Here is one …”/”Here are two …”) allowed participants to predict the upcoming word/picture as well as its future location, resulting in anticipatory eye movements. The same linguistic cues were used in the “Language-Central” condition but all visual stimuli were presented centrally, thus minimizing visuospatial processing demands. In the “Visual-VW” condition, a fixation cross cued eye movements to the object’s future location. The duration of the predictive window was jittered across trials (cf. [2]). In all conditions, the cued picture then re-appeared simultaneously with an auditory word and participants performed a word-picture matching task (button press for match (87.5% of trials); no response for mismatch). There were four runs, each with 16 trials/condition. Previous analyses of the behavioral data [1] demonstrated that Language-VW cues reliably elicited anticipatory fixations to the object’s future location, and RTs were significantly faster for Language-VW/Language-Central than Visual-VW trials, suggesting that linguistic cues facilitated subsequent word processing. fMRI analysis (SPM12) consisted of preprocessing and GLM specification in which three subevents (picture presentation, predictive cue, word-picture matching) were modeled for each condition. Whole-brain analyses were conducted (voxel-wise FWE = 0.05, k ≥ 3). Activation patterns associated with linguistic predictive cues were identified by comparing Language-VW to Visual-VW. Activation patterns associated with visuospatial processing were identified by the contrast Language-VW>Language-Central. Results. During the predictive cue, greater activation was found for Language-VW > Visual-VW in the right pars orbitalis, whereas visual predictive cues (Visual-VW>Language-VW) elicited greater activation in the bilateral lateral occipital gyri. During word-picture matching, the Visual-VW>Language-VW contrast yielded activation in the right superior temporal gyrus, whereas the reverse contrast yielded no significant results. Additionally, Language-VW>Language Central elicited greater activation in the right precuneus during word-picture matching. Conclusion. Consistent with the RT results, language cues appear to have facilitated the prediction of an auditory word form. When presented with a language cue (vs. a visual cue), participants showed increased activation in the right pars orbitalis, which may be an index of word prediction. Language cues also led to a relative decrease in activation in the right STG during word processing, which may reflect pre-activation of the auditory word form. This study demonstrates the utility of combined visual-world eye-tracking/fMRI to detect neural correlates of word prediction and processing.
References [1] Mack, 2021. Lang. Cogn. Neurosci. [2] Bonhage, 2015. Cortex, 68.

Topic Areas: Meaning: Lexical Semantics; Methods

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Searchlight RSA using multiple representational models reveals the detailed structure of the semantic system

Leonardo Fernandino[1], Jia-Qing Tong[1], Colin Humphries[1], Lisa Conant[1], Jeffrey Binder[1]; [1]Medical College of Wisconsin

Functional neuroimaging studies of semantic language processing have implicated a set of heteromodal cortical regions in the inferior parietal lobule, lateral and ventral temporal cortex, medial parietal cortex, and medial and lateral prefrontal cortex (the “semantic network”). Here we used a surface-based representational similarity analysis (RSA) searchlight approach with high-resolution fMRI to investigate the fine-grained structure of this network. The aim was to identify the precise cortical locations of the constituent functional nodes and to get insight into possible differences in their representational structures. Our approach combined RSA results for 6 different models of word semantics: 2 experience-based models (Exp48 and SM8), 2 taxonomic models (Categorical and Wordnet), and 2 distributional models (word2vec and GloVe). We expected that the commonalities and differences between the representational structures encoded in these models would reveal fine-grained distinctions between functional areas making up the semantic network. Methods: Thirty-six adult participants performed a semantic judgment task on individual words while undergoing fMRI. The stimulus set consisted of 320 English nouns, half denoting objects (e.g., “fork”, “motorcycle”, “snake”) and half denoting events (e.g., “laughter”, “convention”, “flood”). The task consisted of rating each object or event according to how often the participant encountered them in their daily lives on a 1-3 scale, responding via key press. The entire stimulus set was presented 6 times over the course of 3 scanning sessions, in randomized order within each presentation. MR imaging was performed with a 3T scanner. Each session included 8 functional scans (4x multiband, TR = 1500 ms, TE = 23 ms, 512 volumes, voxel size = 2 x 2 x 2 mm). A general linear model was used to generate activation (beta) maps for each noun relative to the mean signal across all other nouns. Response time, response key pressed, number of letters for each word, and head motion parameters were included as regressors of no interest. Searchlight RSA was performed using 2-dimensional patches (5-mm radius) on the reconstructed cortical surface. Vertices in the patch were used to select cortical voxels in the participant’s native volume space, and the RSA score was mapped to the central vertex. Group-level analysis was performed on the RSA correlation score maps after aligning each individual map to a common surface template. Permutation testing was used to determine cluster-level statistical significance. Maps were thresholded at $p < 0.001$ at vertex level and cluster-corrected $p < 0.01$. All models predicted representational similarity structure in the angular gyrus (AG), anterior superior temporal sulcus (aSTS), inferior frontal gyrus (IFG), ventral premotor cortex (area 6r), superior frontal sulcus (SFS) and gyrus (SFG), posterior cingulate gyrus (PCG), precuneus (PreCun), and collateral sulcus (CS), all left-lateralized. Only taxonomic and experiential models predicted activity in frontal areas 55b and 10 and in the posterior STS, indicating a difference in representational structure. Averaging the t statistic across the 6 models at each vertex revealed over two dozen distinct RSA peaks in those areas. These results provide the most detailed characterization to date of the functional neuroanatomy of the semantic system.

Topic Areas: Meaning: Lexical Semantics; Methods

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The cortical representation of body part concepts

Stephen Mazurchuk[1], Leonardo Fernandino[1], Jia-Qing Tong[1], Colin Humphries[1], Lisa L Conant[1], Jeffrey R Binder[1]; [1]Medical College Wisconsin

Intro: Category-specific deficits have motivated much of the inquiry on the organization of semantic knowledge. There is an extensive neuroimaging literature on category-specific brain regions engaged during naming visually presented objects (Damasio et al. 1996, Martin et al. 1996), with particular emphasis on the contrasts of animals versus tools, and living versus non-living objects. Despite many decades of interest in the neural representation of the body (Head et al. 1911, Pick 1922), and reports of patients with selective impairment or preservation of body representations (Suzuki et al. 1997, Shelton et al. 1998), there is still little known about the processing of body part concepts as a semantic category (Coslett et al. 2002). FMRI work in this domain has focused almost exclusively on the visual perception of body parts, leaving unclear the distinctiveness of this category when lexically accessed (Devlin et al. 2005). Here we report a study comparing the processing of words denoting body part concepts with words from three other frequently studied object categories. Methods: 15 healthy adult participants were scanned using 3T simultaneous multi-slice fMRI. Stimuli consisted of 200 nouns chosen from the 4 conceptual categories of animals, manipulable artifacts, plants/food, and body parts (50 words per category). Categories were matched on word length, orthographic typicality, word frequency, and lexical decision accuracy. Stimuli were presented visually in an event-related design while participants performed a familiarity judgment task. The entire word list was randomized and repeated 6 times across 3 scanning sessions. Data were preprocessed and projected to a common surface using fmriprep, and mass univariate analysis was performed with AFNI's 3dREMLFit. These results were then smoothed prior to group level analyses consisting of single-sample t-tests using FSL's PALM. The reported results are familywise error corrected with a cluster-forming threshold of $z > 2.2$ ($p < .01$) and significance level of $\alpha < .05$. Results: Compared to the other 3 categories, body part concepts elicited stronger activation in the left supramarginal gyrus (SMG), posterior superior temporal sulcus (pSTS), and posterior middle temporal gyrus (pMTG). Conclusion: The regions showing stronger activation for body part concepts in our analysis are similar to areas previously associated with observation and performance of hand actions and object-directed hand movements (Caspers et al. 2010, Grosbras et al. 2012). Activation of the SMG and pMTG was also previously shown to reflect manipulability ratings for noun concepts (Fernandino et al. 2016). We hypothesize that the body part concept representation arises from a combination of input from motor, tactile, proprioceptive, and visual experiential channels that converge in the SMG and pMTG.

Topic Areas: Meaning: Lexical Semantics; Multisensory or Sensorimotor Integration

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Symbolic Representation of Abstract Concepts using the N400 Mismatch Effect

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Introduction: The representation of concepts using symbols is central to human communication and allows complex ideas and notions to be illustrated with simple letter strings, images, and animations. EEG/ERP has been used to illustrate neurological behaviors that underlie symbol-to-concept matching. Specifically, the N400 response has been shown to be sensitive to semantic expectancies in neurotypical individuals. Many past investigations have relied on pairing highly imageable, concrete stimuli with word or images pairs (i.e., word ‘dog’ with image of ‘dog’). We sought to explore the N400 across symbol modalities (words, images) as they relate to novel abstract concept animations. We examined the N400 mismatch potential in response to five-second animations depicted specific abstract concepts. We hypothesized that ‘mismatched’ words/images that are not associated, or related to target animations would elicit an N400 response, while potentials related to ‘matching’ words/images would remain largely unchanged. Methods: We recorded ERP responses using a Neuroelectrics Starstim-R32 amplifier as participants (N=20) observed 35 animations representing abstract concepts (e.g., competition, freedom) and words/images that were a either a symbolic ‘match’ (e.g., word compete, freedom), semantic ‘associate’ (e.g., word trophy, escape), or ‘mismatch’ (e.g., word explain, mug) of the animation. This resulted in 210 total trials per participant. We analyzed responses of 10 posterior-occipital electrode locations associated with semantic processing. EEG signals were filtered from 0.1-100 Hz. Data were epoched from -100-800 ms relative to word/image onset, and baseline corrected to 100 ms prestimulus. After eliminated artifacts (e.g., eyeblinks) using ERPlab software, this resulted in about 2,000 trials per condition across participants. We conducted a repeated-measures, two-tailed permutation test based on the t-max statistic using a family-wise alpha level of 0.05 to detect reliable differences between matching, associate, and mismatching conditions. Timepoints between 350-550 ms at 10 electrode locations were included in the test. This resulted in a total of 1212 comparisons. 2500 random within-participant permutations of the data were used to estimate the distribution of the null hypothesis. Thus, any differences in the original data that exceeded a t-score of +/-3.29 (df=20) were deemed reliable. Results: Overall, the ‘mismatch’ condition achieved the most negative deflection when compared to ‘match’ and ‘associate’ condition potentials. These differences were illustrated by a left lateralized, posterior topographical distribution of negativity. Specifically, the greatest mismatch effect was identified between ‘associate’ and ‘mismatch’ waveforms at CP6 (p=.04) and Pz (p=.04) electrode locations. Further these differences were found only in the word-to-animation pairings. This finding runs somewhat contrary to our hypothesis, where we predicted the greatest differences would arise between ‘match’ and ‘mismatch’ waveforms. Conclusion: We identified the potential for N400 mismatch responses to illustrate abstract concept processing across symbol modalities (words and images). Specifically, we illustrated a mismatch-effect when contrasting ‘associate’ waveforms with ‘mismatch’ waveforms. These results could suggest a preference for associated words/images (e.g., ‘trophy’ representing competition) over descriptive labels (e.g., ‘racing’ representing competition) in semantic processing of abstract concepts. In all, this work provides empirical support for unique electrophysiology associated with abstract concepts which warrants an expanded investigation.

Topic Areas: Meaning: Combinatorial Semantics; Meaning: Lexical Semantics

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The language network reliably tracks non-linguistic meaningful stimuli in a naturalistic setting

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The language network, comprised of brain regions in the left frontal and temporal cortex, responds robustly and reliably during language comprehension, but not during many non-linguistic cognitive tasks, including arithmetic, music perception, logical reasoning, executive function tasks, action/gesture observation, mentalizing, and even the processing of computer code (e.g., Fedorenko & Blank, 2020). However, one domain whose relationship with language remains debated is abstract semantics: our conceptual knowledge of the world. Given that the language network responds robustly to meaningful linguistic stimuli, could some of this response be driven by the presence of rich conceptual representations encoded in linguistic inputs? Past studies have reported responses in the language regions to pictures of objects and events (e.g., Devereaux et al., 2013; Handjaras et al., 2017; Visser et al., 2012; Ivanova et al., 2021), albeit lower than the response to linguistic stimuli. However, in static images, the possibility of linguistic re-coding of visual semantic information is difficult to rule out. In this study, we used a naturalistic experimental paradigm to ask whether the cognitive and neural resources responsible for language processing are also recruited for processing semantically rich audiovisual inputs that do not contain language. Here, we adopted the inter-subject correlation (ISC) approach (Hasson et al., 2008) to examine the tracking of non-linguistic meaningful naturalistic stimuli by the language network (which was defined in each individual using a localizer task; Fedorenko et al., 2010). The use of rich naturalistic stimuli should minimize the probability of re-coding the information into a linguistic format. If the language network represents/processes abstract conceptual information, then we should observe correlated patterns of BOLD signal fluctuations across participants during the presentation of naturalistic stimuli. In fMRI, forty-six participants were presented with 10 naturalistic stimuli (each ~5 minutes long): 4 critical, meaningful non-linguistic, stimuli (silent films and animations, and a “story” made up of sound effects with no linguistic information); 4 linguistic stimuli (stories and dialogs); and 2 non-linguistic stimuli with no/minimal propositional meaning (a musical piece and a movie of changing kaleidoscope images). Across all the regions of the language network, non-linguistic meaningful stimuli elicited reliable ISCs. These ISCs were substantially lower in magnitude than the ISCs elicited by linguistic stimuli, but stronger than the ISCs elicited by non-linguistic stimuli without propositional content. These results suggest that the language network encodes abstract semantic content even from entirely non-linguistic—visual and auditory—stimuli.

Topic Areas: Meaning: Combinatorial Semantics; Methods

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Semantic and syntactic specialization during auditory sentence processing in 7-8-year-old children

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Previous studies indicate that adults show specialized syntactic and semantic processes in both the temporal and frontal lobes during language comprehension. Neuro-cognitive models of language development argue that this specialization appears earlier in the temporal than the frontal lobe. However, there is little evidence supporting this progression. Our recently published study (Wang, Rice & Booth, 2020), using multivoxel pattern analyses (MVPA), detected that children as young as 5- to 6-years-old exhibit specialization and integration in the temporal lobe, but not the frontal lobe. In the current study, we used the same approach to examine semantic and syntactic specialization in children ages 7 to 8 years old. This project is a registered report with an in-principal acceptance and represents an important step forward in testing neuro-cognitive models of language processing in children. Seventy-six children [M(SD)age = 7.35 (0.30), 46 girls] participated in the current study. We used a semantic plausibility judgment task and a syntactic grammaticality judgment task to tap into semantic and syntactic processing during auditory sentence comprehension. In our planned analysis using MVPA, we compared brain activation patterns between correct, error-free, sentences: sentences with no incongruencies in the semantic task and sentences with no grammatical errors in the syntactic task. In the exploratory analyses, we used the same method but compared brain activation patterns between incorrect sentences: sentences with incongruencies between the verb and object in the semantic task and the sentences with finiteness violations in the syntactic task. In addition, we used traditional univariate analyses to compare brain activation between tasks during both correct and incorrect sentence processing. Using MVPA, we found support for semantic specialization in the left MTG for correct sentences and in the triangular part of the left IFG for incorrect sentences. We also found that the left STG played an integration role and was sensitive to both semantic and syntactic processing during both correct and incorrect sentence processing. There was no evidence for syntactic specialization. Although both the temporal and the frontal lobes were activated during correct and incorrect sentence processing, no semantic or syntactic specialization was observed using univariate analyses. Together with our previous study on 5- to 6-year-old children, which showed semantic specialization in the temporal lobe, the current study suggests a developmental progression to semantic specialization in the frontal lobe. Although our study employed tasks that explicitly required syntactic and semantic processing, we still found no support for syntactic specialization in 7- to 8-year-old children. Thus, for the next step, we aim to examine if 9- to 10-year-old children show syntactic specialization as proposed by developmental models of language comprehension.

Topic Areas: Syntax; Meaning: Lexical Semantics

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ERP profiles of L1 and L2 processing of adjective-noun word order violations in Mandarin and English

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INTRODUCTION: Steinhauer (2014) compared L1 and L2 processing of English adjective-noun word order. L1 and L2 groups showed the same ERP profile, a biphasic N400-P600 effect elicited at the second word in the violation condition (e.g., “small dog” vs “dog *small”). Thus, L2 speakers can show native-like processing of adjective-noun pairs, even when their L1 word order differs from English. The present experiment extended consideration to Mandarin Chinese, where adjectives share features with stative verbs (e.g., 张三真聪明, Zhangsan really intelligent, without copula; Paul, 2010). This means that even though adjectives typically precede nouns (短袖, short sleeves), the reverse is also possible (袖短, sleeves short). While similar adjective-noun order between English and Mandarin suggests no specific problem for L2 acquisition, local grammaticality of the noun-adjective order in Mandarin may render these structures more ambiguous. Given these crosslinguistic differences, we investigated 1) whether Mandarin adjective-noun word order violations would elicit the same ERP effects as previously reported in English, 2) whether L2 learners of Mandarin (English L1) can display native-like processing of adjective-noun word order, and 3) whether we could replicate the original ERP results in L1 English speakers. METHODS: To most closely mirror English grammar, we limited Mandarin materials to one-syllable adjectives that can be used naturally without the relativizer DE. We also constructed a preceding sentence context that highly restricted the critical adjective-noun pair to only be grammatical in the standard adjective-noun order (e.g., 玛丽夏天套上短袖/袖*短了, In summer Mary wears short sleeves / sleeves *short). We chose 60 such adjective-noun pairs, and L1 (N=29) and L2 (N=20) participants read the sentences presented word-by-word (SOA = 750 ms) while their EEG was recorded. The Mandarin L2 speakers (N=16, L1 English) also completed the English experiment with the materials from Steinhauer (2014). RESULTS: L1 Mandarin ERPs showed the same N400-P600 pattern for the word order violation as previously reported for English, but also showed a greater N400 for the correct word order at the first word. While L2 Mandarin ERPs showed a trend towards an N400-P600 effect for the violation ($p = 0.1$), it did not reach significance. The N400-P600 pattern was replicated, however, in the L2 Mandarin participants reading in their L1 English. CONCLUSION: These data suggest that in native speakers, adjective-noun order violations in Mandarin are processed by the same mechanism as in English, but the greater N400 for the correct order at the position of the first word was different from the original study. We interpret this finding as stemming from local lexical effects of single-syllable adjectives, which unlike in English may form a single lexical unit with the single syllable noun. Future experiments will need to consider other Mandarin adjective structures to fully qualify this effect. Although L2 Mandarin processing showed only a non-significant N400-P600 tendency, Mandarin proficiency may have played a role; thus, it remains possible that higher proficiency L2 speakers would show the same pattern as native speakers.

Topic Areas: Multilingualism; Syntax

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Robust effects of working memory load during naturalistic language comprehension in language-selective cortex

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Some theories of human language comprehension posit processes that retrieve and update representations in working memory (WM; Gibson, 2000; Lewis & Vasishth, 2005). Others hypothesize prediction processes that might underlie comprehension (Levy, 2008). Prior behavioral and neuroimaging experiments have supported effects of memory (Fiebach et al., 2001) and prediction (Bonhage et al., 2015) in isolation using carefully constructed stimuli. Empirically distinguishing these two classes of accounts is generally challenging (Levy & Gibson, 2013), and many previously reported effects of syntactic processing (e.g., syntactic anomalies; Osterhout & Holcomb, 1992) are consistent with both theories. Further complicating matters are poorly understood effects of experimental design in studies of human language comprehension (Hasson et al, 2018). Although studies overwhelmingly investigate syntax using carefully selected or hand-crafted sentences presented out of context, linguistic input in typical conditions is richly varied and contextualized, and growing neuroscientific evidence indicates that artificial stimuli and tasks may engage cognitive mechanisms that are not central to language processing (Diachek, Blank, & Siegelman et al., 2020). Importantly, recent naturalistic behavioral studies have generally not shown strong evidence of memory retrieval costs (Demberg & Keller, 2008), casting doubt on theories that hypothesize syntax-driven memory operations as central to comprehension. However, it is possible that WM effects are underlyingly present without registering strongly in behavioral measures like reading time, which may aggregate over a range of mental processes (Rayner, 1998). Furthermore, granting a core role of WM in naturalistic language comprehension, debate exists about the extent of overlap between neural mechanisms that support WM for language processing vs. WM as required by other domains of cognition. Some have argued for language-specific working memory resources (Caplan & Waters, 1999), whereas others have argued that language comprehension relies primarily on domain-general WM resources (Amici et al., 2007). This study jointly investigates the existence and functional specificity of WM load during language comprehension using data from a large-scale naturalistic fMRI study (Shain, Blank et al., 2020) under rigorous controls for word predictability. We first explore multiple plausible implementations of prior theories of WM in language processing, then evaluate the most robust of these on unseen data. In so doing, we examine neural responses in two candidate brain networks, each functionally localized in individual participants: the language-selective network (LANG; Fedorenko et al., 2010) and the domain-general multiple-demand (MD) network implicated in executive functions, including WM (Duncan, 2010). Responses in the MD network show no evidence of an association with any of the estimators of working memory load explored here. Responses in the language network show clear and generalizable WM effects, especially as described by the Dependency Locality Theory (Gibson, 200). Based on these results, we argue (1) that a core function of the human language processor is to compose representations in working memory based on syntactic cues, even in naturalistic settings, (2) that dependency locality best describes the cost of these composition operations among extant broad-coverage theories of WM in language processing, and (3) that these operations are implemented locally within the language-selective cortical network.

Topic Areas: Syntax; Computational Approaches

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P600 and task effects

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We conducted two experiments to investigate the influence of task demands on sentence processing using event-related potential (ERP) methods. Stimuli from Osterhout and Holcomb (1992) were used to examine effects on the P600 component, a marker of syntactic anomaly. Participants read sentences (critical words are underlined) such as (i) The broker persuaded _*to_ conceal the transaction _was_ sent to jail vs. (ii) The broker planned _ to_ conceal the transaction *_was_ sent to jail. In Experiment 1, 25 participants read these sentences with yes/no comprehension questions (e.g., Did the broker plan something?), in contrast to Osterhout & Holcomb's use of grammaticality acceptability tasks. We expected to replicate findings from the original work, where P600 effects were found at 'to' in (i) vs. (ii) and at 'was' in (ii) vs. (i). While P600 effects at 'to' did not replicate, the P600 effect downstream at 'was' did. In Experiment 2, 21 participants read these sentences, where no questions were asked at critical trials. Reduced P600 effects were expected due to lack of attention at critical trials. We did not find any evidence of P600 effects at 'to' or 'was' at all. Instead, a nearly significant long-lasting positivity effect was found at the final word 'jail' in (ii) vs. (i) suggesting that participants wait to integrate for meaning. Both experiments did find a significant long-lasting negativity at 'conceal', suggesting that participants were sensitive to deletion associated with the reduced relative clause. Results are discussed in terms of noisy channel hypotheses of sentence processing.

Topic Areas: Syntax; Control, Selection, and Executive Processes

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Generalized additive mixed modeling of EEG supports dual-route account of morphosyntax in finding no word frequency effects on grammar processing

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A critical component of understanding how our minds process language is accounting for inflected forms, e.g., the difference between "eat" and "eats" in a sentence like "They eat/*eats." Single-route models of morphosyntax posit that processing of regular inflections involves associative memory-based storage (e.g., McClelland & Patterson, 2002), whereas dual-route models alternately propose rule-governed composition (e.g., Pinker & Ullman, 2002). These accounts can be tested by their divergent predictions regarding whether word frequency—an indirect approximation of the strength of stored representations—affects processing of regular morphosyntactic inflections (as in the single-route model) or not (dual-route model). To our knowledge, the only study to test this using electroencephalography (EEG) comes from Allen, Badecker, and Osterhout (2003), who examined whether grammatical processing of verb tense violations ("will work/*worked") was affected by word frequency (low-/high-frequency). No interaction between grammaticality and word frequency was found for regular forms, consistent with the dual-route model's predictions. However, reproduction of these results for a different regularly inflected morphosyntactic form would increase the generalizability and validity of the findings. Furthermore, applying a newer statistical analytical approach can address limits in statistical power from their event-related potential-based analysis (arising from time-window averaging of EEG amplitudes [Fields & Kuperberg, 2020] and from dichotomization into low-/high-frequency bins [Baayen, 2004]), as well as theoretical issues related to the assumption that the time course of language processing is identical across words/participants (see Sassenhagen, Schlesewsky, & Bornkessel-Schlesewsky, 2014). Thus, we extend Allen et al. (2003) in a conceptual replication experiment by using generalized additive mixed models (GAMM), which retain per-trial and per-time sample information for improved statistical power while allowing the time course of language processing to vary idiosyncratically across participants and words. Our data come from 51 English native speakers who completed a grammaticality judgment task (GJT) while reading 124 experimental sentences that either did or did not contain a determiner-noun agreement violation (e.g., "this/*these school"). We follow the GAMM-fitting procedure based on Wieling (2018), with word frequency taken from the British National Corpus as a continuous predictor. Our pre-planned analysis involved sequentially fitting models to predict mean EEG amplitude in an eight-electrode region of interest (based on Tanner, 2019) by (a) adding fixed linear terms for word grammatical/ungrammatical status and frequency while allowing amplitude to vary across time; (b) allowing effects of grammaticality and frequency to vary non-linearly across time; and (c) testing whether the grammaticality-by-frequency interaction significantly improved model fit as per the Akaike Information Criterion (AIC). Our results reproduced previously-reported main effects of frequency and grammaticality, with significant effects for these parametric coefficient terms at $p < .05$. Critically, we found no significant improvement to model fit when including the grammaticality-by-frequency interaction, as per the significance criterion of a minimum reduction threshold of 2 AIC units for selecting a more complex model (following Wieling, 2018). Our results are consistent with findings from Allen et al. (2003) and align with the dual-route model's account of rule-based composition as a mechanism that underlies processing of regularly-inflected morphosyntactic forms.

Topic Areas: Syntax; Methods

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An investigation of the neuronal signature of word order effects in Russian

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Restrictive context can predict a specific word (e.g. Kuperberg & Jaeger, 2016), but is infrequent in naturalistic conditions. A graded prediction of upcoming word features is a more robust mechanism (Luke & Christianson, 2016). Electrophysiological studies have identified a positive event-related (ERP) component with a peak between 500-700ms (P600) that reflects the need to update the mental representation of an entire utterance when the upcoming input renders the previous mental representation untenable (Brouwer, et al., 2012). Posterior P600 was reported for structural and semantic revisions: grammatical (Frederici et al., 1996) and semantic violations (sometimes preceded by N400; see Kuperberg, 2013 for a review) or unexpected garden-path sentences (Qian et al., 2018). Frontal P600 is associated with syntactically complex grammatical sentences without the semantic revision (Jackson et al., 2020; Kaan & Swab, 2003). However, prior neurological studies used strict word order Germanic languages where the ability to control the target length or the word count and length of the preceding context is difficult. Moreover, the ERP is an aggregate signal that pulls on different frequency bands. Thus, time-frequency measures pinpoint what frequency oscillation at what topography contributes to the ERP components. This project investigated the role of the preceding word order on the target word, controlling for word length and the preceding context. We examined neuronal brain responses evoked by violations of canonicity of word order and grammaticality in Russian. Method: Russian's free word order and rich inflectional system allowed us to examine separate contributions of canonicity and grammaticality. Electrophysiological responses were recorded from 12 Native Russian speakers (6 female; mean age=25) during word-by-word (500 SOA) reading. Grammaticality and canonicity were crossed in a 2x2 Latin square design (SVO[baseline]/SVS/OVS/OVO; a total of 160 4-sentence units). Semantic plausibility and predictability of the arguments was controlled through norming. Word order frequency: SVO(60%)/OVS(30%) (Lobanova, 2011). ERPs were baseline corrected to the first noun (-100:0). Time-frequency analyses used a Slepian sequence (multitaper filter with the Hanning taper) with the adaptive window in Fieldtrip open-source software (Oostenveld et al., 2011). ERP analyses revealed grammaticality effects in the P600 window with frontocentral topography, but only for the canonical word order (SVS>SVO, $p<.01$). Evoked power (EP) and intertrial coherence (ITC) phase-locked to the target word revealed analogous interaction between grammaticality and canonicity in the delta band (2-3hz) correlated to the P600 time window with elevated delta level for ungrammatical endings in the canonical word order SVS > SVO > OVS > OVO ($p<.01$). First, grammaticality elicited an effect only in the canonical SVO with the ungrammatical second subject (SVS) but not the second object (OVO) in the noncanonical OVS. Second, our study enriches the literature on P600 and delta oscillations by demonstrating that evoked and ITC delta power is sensitive to morphosyntactic information. Finally, our study contributes to the growing research on graded prediction by showing that preceding context can induce the expectations regarding word order and morphosyntactic case inflections as reflected in the electrophysiology of neuronal oscillations.

Topic Areas: Syntax; Morphology

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Heterogeneous ERP patterns for different error types in French complex noun phrases

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INTRODUCTION: The French noun phrase (NP) offers parameters to study morphosyntactic (gender) and syntactic error processing. Gender agreement on adjectives can be irregularly marked (e.g., vert/e [vɛʁ/t], 'green.M/F'), while singular definite determiners carry predictable transparent vowels for agreement (e.g., le/la, 'the.M/F'). Furthermore, French lexically constrains adjective position: size adjectives are prenominal while most others are postnominal. Both syntactic and morphosyntactic violations often elicit a biphasic ERP pattern: LAN (left-anterior negativities) or N400s followed by posterior positivities (P600). LANs are linked to rule-based processing, N400s to lexical processing, and P600s to integration and repair (Molinaro et al. 2011; Steinhauer & Connolly 2008). Our picture-sentence matching paradigm tested four error types in French adjective processing. METHODS: 22 adults saw an image, then heard a correct or ungrammatical spoken sentence describing it and completed a judgment task. Six NP conditions each contained an adjective (pre- or postnominal adjective) and a prepositional phrase: 1. Correct: Je vois le soulier vert sur la table 'I see the.M shoe.M green.M on the table' 2. Adjective agreement error: Je vois le soulier *verte 'green.F'... 3. Determiner agreement error: Je vois *la 'the.F' soulier vert … 4. Prenominal adjective inversion: Je vois le soulier *grand 'big.PRE' … 5. Postnominal adjective inversion: Je vois le vert 'green.POST' *soulier … 6. Noun-drop: Je vois le vert __ dans …, I see the green (one) in … Each condition was analyzed time-locked to the adjective or determiner. Correct conditions (1 and 6) served as grammatical controls, and (6) controlled for strategic processing in (5). Agreement errors should elicit N400s on adjectives (2), and LANs on determiners (3), both followed by P600s. Since violations in (4–5) depend on the adjective's lexical status, we expected N400-P600s, with earlier effects on the adjective in (5–6), as they signal either an unusual word order (6) or a subsequent violation (5). RESULTS: In all but one condition, errors elicited negativities followed by positivities. However, adjective agreement errors (2) elicited LANs (300–500 ms), and large P600s (650–1050 ms), while determiner errors (3) elicited sustained bilateral anterior negativities (400–500 ms) and small P600s (750–1050 ms). Inverted prenominal adjectives (4) elicited biphasic N400-P600s. Postnominal adjective inversion (5) and noun-drop (6) – an unusual but legal word order – both elicited small central positivities at 'vert', followed by a non-significant N400 in (5). CONCLUSION: All P600s were as predicted. The LAN in (2) suggests these violations rely on rule-based processing. The frontal negativity in (3) resembles a phonological mismatch negativity (Connolly & Phillips, 1994) elicited by the mismatch between the image (e.g., shoe.M) and determiner's gender (the.F). The large N400 in (4) is in line with a salient word-order violation tied to lexical status (prenominal adjectives). Condition (5) illustrates that unusual (grammatical) word orders can initiate syntactic checks (early P600s), while the small N400 on the (ungrammatical) noun conforms with the adjective's postnominal status. Overall, the data suggest that ERPs for adjectival violations in French NPs are modulated by a combination of rule-based, lexical, and phonological factors.

Topic Areas: Syntax; Morphology

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The role of inferior frontal regions in phonological competition: Preliminary evidence from trial-level integration of eye-tracking with fMRI *Sandbox Series*

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Purpose. This in-progress study uses concurrent eye-tracking/fMRI to investigate the role of the inferior frontal gyri (IFG) in phonological competition. Previous studies demonstrated increased activation in the bilateral IFG in the presence of an onset competitor picture (e.g., a cat for target cap) [1-2]. In addition, Broca's aphasia, which typically involves damage to the left IFG, is associated with reduced onset competition and increased rhyme competition (e.g., fixations on a map for target cap) [3], suggesting that this region supports incremental word recognition processes that yield onset competition. This study has two goals: (1) to identify neural correlates of phonological competition through trial-level integration of eye-tracking and fMRI data; (2) to test the hypothesis that onset (vs. rhyme) competition is associated with greater IFG activation. Methods. Six young adults participated before data collection was paused due to Covid-19. Two participants were excluded due to motion or data collection problems. In each trial, participants saw four pictures, heard a word, and clicked on the target picture. There were two runs, each with 32 trials per condition (onset competitor, rhyme competitor, and filler), in an event-related design with jittered ITIs. For each onset and rhyme trial, we computed an eye-tracking measure of phonological competition ("ET"): the total fixation time on the competitor picture divided by the total fixation time on all pictures. fMRI analysis (SPM12) consisted of preprocessing and GLM specification with four conditions per run: onset trials, rhyme trials, filler trials, and excluded trials (due to incorrect responses or poor eye-tracking data). The phonological competition "ET" measure parametrically modulated the onset and rhyme trials. We analyzed data individually for the following contrasts: the overall effect of phonological competition (onset-ET + rhyme-ET) and pairwise comparison of onset vs. rhyme trials and onset-ET vs. rhyme-ET. The analysis was limited to the bilateral IFG (regions 44 and 45) using an ROI mask created with the SPM Anatomy Toolbox [4]. We report significant clusters using a small-volume correction (peak-level FWE < 0.05). Results. Greater overall phonological competition was associated with increased activation within the IFG for three participants (bilateral in one; left in two). Onset > rhyme trials yielded activation in the bilateral IFG for one participant, whereas rhyme > onset trials did so in the left IFG for another. For two participants, very small (k<3) left IFG clusters were found for onset > rhyme ET. Conclusion and future directions. The association between IFG activation and overall phonological competition in three participants supports the validity of trial-level integration of eye-tracking with fMRI data. We found limited evidence that IFG activation is more strongly associated with onset than rhyme competition, as measured with eye-tracking. After data collection is completed in 2021, we plan to perform these analyses at the group level. Further, we will use IFG seed regions to test for differential connectivity patterns associated with onset vs. rhyme competition. References [1] Luthra, 2019. Lang. Cogn. Neurosci., 34(2). [2] Righi, 2010. J. Cogn. Neurosci., 22(2). [3] Mirman, 2011. Brain Lang., 117. [4] Eickhoff, 2005. Neuroimage, 25(4).

Topic Areas: Phonology and Phonological Working Memory; Control, Selection, and Executive Processes

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Combining EEG and eye-tracking to investigate the prediction of upcoming speech in naturalistic virtual environments: a 3D visual world paradigm *Sandbox Series*

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The human capacity to rapidly and efficiently process speech may be facilitated by expectations about upcoming speech content. Listeners' eye gaze has indeed been shown to move towards a referent before it is mentioned when the prior linguistic input is highly constraining. We recently replicated this canonical finding in more naturalistic settings, in virtual reality, while a virtual speaker was present (Huizeling et al., 2021; PsyArXiv). We additionally showed that disfluencies in speech ("uh") reduced the proportion of fixations towards the predicted object. Instead, fixations towards the virtual speaker increased. However, it remained unclear whether looks towards the speaker reflected a reduced confidence in the initial prediction and the listener waiting for the sentence to be disambiguated, or, alternatively, a mere increase in attention towards incoming speech, without a change to the prediction. Another way to investigate linguistic prediction is with electroencephalography (EEG). Earlier work has consistently observed reduced N400 amplitude when the semantic content of a word was easier to integrate with the preceding context, e.g. when a word was highly predictable. While eye movements provide vital information about whether a referent has been predicted before it is mentioned, N400 amplitude modulations may provide information about the ease of word processing the moment the word is perceived. In an ongoing proof-of-principle investigation, we are leveraging these complementary advantages of EEG and eye-tracking to study linguistic prediction in naturalistic, virtual environments. This method will allow us specifically to uncover new theoretical insights into the influence of disfluencies on the prediction of speech. Participants (n=18; target n=32) listened to sentences spoken by a virtual agent during a virtual tour of eight scenes (e.g., office, street, canteen). The agent discussed her relation to each scene while participants' eye movements and EEG were recorded. Spoken stimuli, produced by the agent (incl. lip sync and gaze to the participant), were 128 subject-verb-object sentences, pre-recorded by a native Dutch speaker. Sentences were either predictable or unpredictable based on verb constraints, where the verb in the sentence was either related to a single object in the scene (restrictive and predictable), or related to multiple objects in the scene (unrestrictive and unpredictable). In only 50% of sentences the noun referred to an object present in the scene to confirm the participant's prediction. The remaining 50% of sentences mentioned objects absent from the scene, arguably disconfirming the participant's prediction. In a critical window between verb and noun onset, we expect a greater proportion of target object fixations in the restrictive compared to unrestrictive condition. We additionally expect a greater (more negative) N400 response to the noun when the uttered referent is absent from the scene, compared to when the object is present in the scene, an effect that is expected to be greater in restrictive than unrestrictive sentences. Successfully combining EEG and eye-tracking in virtual environments enables new research trajectories that cannot be adequately addressed by any one traditional method in isolation, such as investigating the extent that predictions of upcoming speech are dynamically informed by disfluencies.

Topic Areas: Control, Selection, and Executive Processes; Methods

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The effects of speaker's eye gaze on infants' speech processing and word segmentation *Sandbox Series*

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In face-to-face interactions, speech is inherently multimodal, accompanied by a variety of information such as the speaker's facial expressions, lip movements, and eye gaze. Such cues may facilitate speech processing, and may be especially important for infants, for whom speech processing and word segmentation are challenging tasks. Among these multimodal cues, eye gaze presents itself as a ubiquitous, powerful social cue that facilitates children's learning in various domains of cognitive development, including language development. The ability to establish eye contact with a communication partner and follow their gaze allows infants to orient and attend to the relevant information in the naturally noisy environment. As a result, measures of early gaze following and responses to joint attention correlate positively with receptive and expressive vocabulary (Brooks & Meltzoff, 2008). However, the effects of the speaker's eye gaze on other aspects of language development are less clear. This is an important omission given the potential role of eye gaze as an ostensive cue that optimizes information transfer between the child and the adult (Csibra & Gergely, 2009). Eye gaze might have a general enhancement effect, also facilitating learning in different aspects of language, such as speech perception and word segmentation, by increasing infants' attention to the speech signal. In adult studies, attention to speech has been found to enhance cortical speech tracking (Lesenfants & Francart, 2020; Rimmele et al., 2015). In the current study, we investigated infants' cortical tracking of continuous speech and word segmentation in ostensive and non-ostensive conditions. Typically-developing 10-month-old infants watched videos of an adult Dutch speaker telling stories using infant-directed speech, addressing the infant either with direct or averted eye gaze. The audio-visual stories consisted of four sentences, with one word being repeated in every sentence for each story. Each video was followed by audio-only isolated words (familiar/novel). 32-channel EEG was recorded throughout the experiment. Our aim was to determine (1) if infants' cortical tracking of speech during the audio-visual stories, measured by speech-brain coherence (at the syllable and stressed syllable rates), was associated with word recognition performance (measured by the ERP word familiarity effect at the audio-only isolated words in the 250-500 ms and 600-800 ms time-windows); and (2) whether the ostensiveness of the adult's speech, signalled by their eye gaze direction (direct vs. averted) facilitated cortical tracking of speech and word recognition. We will compare speech brain coherence during the direct gaze vs. averted gaze conditions, and investigate whether the ERP word familiarity effect is larger when the speaker addressed the infant with direct gaze compared to averted gaze during the familiarisation phase. Cluster randomization statistics will be used for the analysis. We aim to include 48 infants in the final dataset, and have currently tested 43 infants. Preliminary results will be presented at the conference.

Topic Areas: Development; Speech Perception

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Anatomical differences in Heschl's gyrus in dyslexia, and in relation to working memory and phonological skill *Sandbox Series*

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Dyslexia is a learning disorder characterized by reading and phonological processing deficits, but also with deficits in other functions such as working memory (Jeffries & Everatt, 2004), rhythm processing (Dellatolas et al., 2009) and visuo-spatial attention (Vidyasagar & Pammer, 2010). Heschl's gyrus (HG), which includes primary auditory cortex (Hall et al., 2003), displays considerable anatomical variability across individuals and across hemispheres (Penhune et al., 1996). Previous studies on the anatomy of HG and of the adjacent planum temporale have revealed an increased incidence of full posterior duplications (Altarelli et al., 2014; Leonard et al., 2001; Serrallach et al., 2016), as well as evidence for a diminished L>R structural asymmetry and trends for overall smaller HG in this disorder (Altarelli et al., 2014). These studies, however, have relied on manual segmentation of auditory cortex sub-regions based on visual inspection of structural MRI, which is more subject to error and to arbitrary decisions than automated segmentation. Here, in data from 18 dyslexic adults and 27 controls, we used the TASH toolbox (Dalboni da Rocha et al., 2020) to automatically segment HG (including single HG and common stem duplications) in 7T structural MRI, from which we extracted HG gray matter volume, white surface area and gray matter thickness. We tested for group differences using one mixed ANCOVA for each anatomical measure. These 2-way mixed ANCOVAs had group (dyslexic and control) as the between-subjects factor and hemisphere as the within-subjects factor, controlling for the covariates of age, sex and the whole brain respective anatomical measure. Results showed: 1) Volume: only significant main effect of group [$F(1,40)=5.65$, $p=0.022$], with smaller bilateral HG in the dyslexic group. The effect of hemisphere and group-by-hemisphere interaction were not significant. 2) Surface area: only significant effect of group [$F(1,40)=4.14$, $p=0.049$], with smaller bilateral HG surface areas in the dyslexic group. The effect of hemisphere and group-by-hemisphere interaction were not significant. 3) Cortical thickness: no significant effects for group, hemisphere nor group-by-hemisphere interaction. Additionally, in 34 adults of these participants (17 with dyslexia), we tested for partial correlations between HG anatomical measures (volume, area and thickness) in each hemisphere and behavioral measures of Spoonerisms (Ecla16+) and Backward Digit Span (WAIS-IV), controlling for age, gender, Raven's score, years of education and the respective hemispheric anatomical measure. The partial correlations revealed the following results: 1) Volume: No significance. 2) Surface area: No significance. 3) Cortical thickness: Spoonerism correlates with both left [$r(27)=0.348$, p(1-tailed)=0.032] and right [$r(27)=0.480$, p(1-tailed)=0.004] HG. Backward Digit Span correlates with left HG [$r(27)=0.508$, p(1-tailed)=0.002]. These results are consistent with previous reports of altered auditory cortex anatomy in dyslexia, and extend them to relationships with behavior. As next step, given the previously reported differences in HG gyrification in dyslexia, we will also explore HG anatomical differences using different versions of TASH, ones which select multiple transverse temporal gyri when they are present. We will also relate difference in gross brain anatomy to myelination differences in these same participants, with the aim of a multimodal characterization of risk factors underlying dyslexia.

Topic Areas: Disorders: Developmental; Perception: Auditory

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Comparing phoneme categories in word production and perception with fMRI *Sandbox Series*

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Historically, speech production and perception have been studied separately. Nevertheless, for most of our language behavior the production and perception of speech act in concert, and consequently understanding the degree of neural overlap between the language modalities is becoming an important question for brain-language models. However, most of the cross-modal research has focused on high-level language operations such as conversational dynamics and message-level processing. Research investigating the degree of neural overlap between production and perception for the building blocks of language, namely words, is much scarcer. Therefore, in the present study we compare the production and perception of words with fMRI, and in particular investigate the spatial representations of phonemes, since different brain-language frameworks make different predictions with respect to the cortical circuitry underpinning word form processing in two modalities. According to Partial Separation Models (PSM) during speech production both frontal and temporal regions are recruited during phonological processing, while only temporal regions are needed for speech perception. In contrast, according to Integration Models (IM) the same frontal and temporal regions are involved in both perception and production. Our regions of interest (ROI) include inferior frontal motor cortex (iFMC) and posterior superior temporal cortex (pSTC). In current study, where data collection has recently started, we contrast these hypotheses by exploring the phoneme mapping recruited within the same participants performing both picture naming (production) and passive listening (perception) tasks. Crucially, the same set of stimuli is used across tasks: 40 French nouns which are minimal pairs, starting with bilabial (b/p) or alveolar (d/t) consonants (e.g. bombe [bomb]-tombe [tomb]) that have dissociable topography in iFMC. 40 participants will be tested (as assessed with power analyses). Importantly, the production and perception tasks are designed to be as similar as possible in structure, and all participants will cycle through all stimuli in both tasks while undergoing BOLD imaging. This will allow us to contrast the same phoneme difference (bilabial/alveolar word-initial speech sounds) across the language modalities. Two analyses are planned: first, 4x2 ANOVA with language modality (perception/production), phoneme type (bilabial/alveolar), area (frontal/temporal), and topography within the ROI (ventral/dorsal) as factors. While PSM predict an interaction between language modalities (namely the absence of motor cortex involvement for the phoneme contrast in speech perception), IM predict the same fronto-temporal sources in both modalities for the bilabial Vs. alveolar phoneme contrast. Hence, if the main effect of language modality factor would be observed, it might be an evidence in favour of PSM. Additionally, finding of the main effect of phoneme type on the topography within the ROI could be a circumstantial evidence for IM. Second, we intend to complement the analysis above with multivariate pattern analyses where we will train classifiers to distinguish phoneme type in one modality, and then test those classifiers in the other. Within-, but no cross-modal generalisation would be consistent with predictions of PSM, and within- and cross-modal generalisation would support the IM. Overall, the current study addresses whether word processing recruits the same or different neural circuits in perception and production modalities.

Topic Areas: Language Production; Speech Perception

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Cortical tracking of linguistic units at different speech rates *Sandbox Series*

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Language comprehension from speech involves the mapping of continuous acoustic signals onto discrete linguistic representations. Recent evidence suggests the brain “tracks” higher-level linguistic structures, such as words and phrases, whose boundaries are not injectively present in the acoustic input. Seminal work using a frequency-tagging approach by Ding and colleagues (2016) showed tracking of words and phrases in artificial syllable sequences lacking any acoustic cues to higher-level structures. Kaufeld and colleagues (2020) extended this finding using naturally spoken stimuli. At the timescale corresponding to the occurrence of phrases in the input, tracking was enhanced for sentences compared to word lists and prosodic jabberwocky. This pattern suggests linguistic structure and meaning shape the neural tracking of speech over and above timing, lexical content, and prosodic information alone. Consistent with this observation, recent accounts of the cortical speech tracking suggest neural oscillations “entrain” to physical acoustics but “synchronize” with abstract linguistic structures that are internally generated (Martin, 2016; 2020; Meyer, Sun, & Martin, 2020) at different speech rates (Kösem et al., 2018). A remaining open question is whether the observed differences in "tracking" by Kaufeld et al. (2020) are tied to specific frequency bands (e.g., delta for phrases, theta for syllables), or whether they relate to the occurrence of linguistic units that are not driven by the timing of acoustic landmarks. Put differently, does the effect scale with the timing of the input? If the neural signal corresponding to tracking of higher-level structures scales injectively with input speech rate, this would suggest that neural tracking readout of higher-level structures is closely tied to the stimulus sensory representation. In contrast, if the timing relationship between input speech rate and tracking readout of higher-level structures is surjective, it would suggest the tracking signal reflects the brain’s transformation of sensory input into other coordinate systems (i.e., that of higher-level linguistic structures) where stimulus timing is not as closely tied to neural representation as in sensation (Martin, 2020). To this end, we varied the speech rate of three experimental conditions (sentence, prosodic jabberwocky, word list) from Kaufeld et al. (2020) with a range of intelligible (k=1,2), less intelligible (k=3), and unintelligible (k=4). In an independent sample, we validated the behavioral impact of speech rates on intelligibility via a transcription task. 28 participants will passively listen to speech at different rates in the MEG and perform an offline transcription task. In sensor space, we will perform a mutual information analysis of speech and the neural response (Keitel & Gross, 2016; Kaufeld et al., 2020) as a function of condition and speech rate. We will also examine effects of structure, meaning, and speech rate on source-localized oscillatory activity within language-related areas. Then we will use transfer entropy (Park et al., 2015) to describe information flow within our source-localized networks. Our speech rate manipulation attempts to replicate previous findings, to map the neural transduction from sensation to comprehension, and to evaluate whether tracking readout distinguishes between stimulus ‘entrainment’ and intrinsic synchronisation (Martin, 2016, 2020; Meyer, Sun, & Martin, 2020).

Topic Areas: Meaning: Combinatorial Semantics; Speech Perception

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New perspectives on the relationship between language aptitude, behaviour and the brain *Sandbox Series*

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Language aptitude (LA) is traditionally defined as a set of individual cognitive skills predictive of success in foreign language attainment (Carroll & Sapon, 1959). From a linguistic perspective, gifted language learners seem highly skilled in sound-symbol associations, rote learning, and/or grammar analytic abilities. Neural markers of LA (or its subcomponents) have also been found: differences in brain morphology, functionality and neural efficiency have been linked to different levels of LA-related abilities (e.g. phoneme categorization, foreign speech production, language analytic abilities) and to the number of language spoken (Golestani, 2014; Golestani et al., 2011; Golestani & Pallier, 2007; Hervais-Adelman et al., 2018; Jouravlev et al., 2021; Kepinska et al., 2017; Reiterer, 2018; Turker et al., 2017). Not surprisingly these differences are observed in areas within the traditional language network. However, it has recently been argued that LA might rely on working memory or other domain-general cognitive processes (Wen et al., 2017), and the question of the relationship between LA and other domains of cognition remains open. The present work aims at framing LA into a comprehensive and multidimensional view, by investigating individual differences in its behavioural and neural markers in a sample representing the whole spectrum of LA. To this end, we will test around 150 monolinguals, multilinguals, (hyper)polyglots, and dyslexic readers through questionnaires, a behavioural test battery and magnetic resonance imaging. Language experience (in each of the languages spoken) and musical literacy will be assessed through questionnaires. Then, we will administer a battery of online and behavioural tests to measure phonological and symbolic association skills, vocabulary learning and morphosyntactic analysis, as well as fluid intelligence, attention, inhibition, arithmetic, musicality, fine motor and auditory perceptual skills. Furthermore, memory tasks will be included to assess visuo-spatial, procedural, declarative, and verbal working memory. Following behavioural testing, we will obtain structural, resting state and functional MRI scans. Behavioural measure aggregation will be performed through Factor Analysis, Structural Equation Modelling and Dimensionality Reduction techniques. This will likely reveal relationships between the various subcomponents of linguistic skill, general and domain-specific cognition, and their contribution to an extended model of LA. Moreover, we expect to observe individual differences in brain morphology, structural covariance and functional connectivity across-subjects, and in relationship with behavioural performance. Our analyses will focus on, but not be limited to, brain function, structure and connectivity within the main language hubs: the superior temporal, inferior frontal and parietal cortices. As a main outcome, we expect behavioural data to reveal the broader nature of language aptitude, outside a strictly linguistic domain. Moreover, it is possible to outline specific outcomes within our broader investigation: in replication of previous studies, we expect the morphology of the auditory and parietal cortical areas to be linked to phonological abilities, and to observe different functional connectivity profiles in relation to grammar analytic abilities. Finally, anatomical, functional and connectivity differences between elective and non-elective multilinguals, if observed, are likely to indicate relative influences of predisposition versus of experience-dependent plasticity, respectively, in language learning (Ressel et al., 2012).

Topic Areas: Multilingualism; Phonology and Phonological Working Memory

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Spatio-temporal dynamics of phonological neighborhood effects in a picture-naming task *Sandbox Series*

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Phonological neighborhood is typically defined as the number of words that can be obtained by manipulating a single phoneme. Words from high-density (HD) phonological neighborhoods (e.g., belt) have many phonological neighbors (e.g., melt, bell, built, belly), whereas words from low-density (LD) phonological neighborhoods (e.g., frog) do not. Taking phonological neighbors into account is important because they are co-activated during word processing. RT effects of phonological neighborhood in picture naming have been reported in both directions (e.g., Diaz et al., 2021; Sadat et al., 2014). Sadat and colleagues (2014) have proposed that the net behavioral effect is a summation of 1) inhibition due to increased lexical competition and 2) facilitation due to increased feedback from the co-activated lexical representations to shared sublexical representations. Consistent with increased lexico-semantic processing and potential competition, HD words elicit larger amplitude negativities in the EEG waveform than LD words (e.g., Winsler et al., 2018). Consistent with facilitated sublexical processing, Diaz et al. (2021) recently reported that HD words elicited a decreased BOLD signal relative to LD words in regions associated with phonology and articulation. Understanding these opposing dynamics of increasing phonological neighborhood would therefore benefit from a method that has both the temporal resolution to distinguish between sublexical and lexical processing and the spatial resolution to determine where in the brain processing is influenced. Intracranial electroencephalography (iEEG) offers such a solution. In an ongoing study, we are recording iEEG data from patients who are undergoing neurological treatment for refractory epilepsy as they name pictures that have either HD or LD names. The 17 patients (ages 21-55; 5 females) who have participated thus far named the pictures in the HD condition faster and more accurately than those in the LD condition overall. We have also identified significant high-frequency band activity in several regions of interest - including the superior temporal and precentral gyri - that were motivated by the fMRI study by Diaz and colleagues (2021). The next step will be to identify the electrodes where stimulus- and response-locked high-frequency band activity significantly differs between the pictures with HD versus LD names. Upon completion, the time course of the effect and the functional significance of the regions in which these electrodes are located will contribute to our understanding of how exactly phonological neighbors influence word production.

Topic Areas: Phonology and Phonological Working Memory; Control, Selection, and Executive Processes

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Using EEG and RSA to test neural computations underlying phonological analysis in spoken language comprehension *Sandbox Series*

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EEG has been used extensively to study the time course of sentence comprehension, with different computations proposed to underlie prominent ERP effects. For example, it has been argued that the increased magnitude of earlier neural responses (~100ms post-stimulus) reflects the magnitude of phonological prediction error (Sohoglu & Davis, eLife, 2020), while later N400 responses reflect the magnitude of semantic prediction error (e.g., Rabovsky, Neuropsychologia, 2020). However, changes in response magnitude are also consistent with other computations, such as those which integrate current words with contexts to sharpen predicted features of the input (Aitchison & Lengyel, Curr Opin Neurobiol, 2017). Therefore, changes in ERP magnitude alone are not sufficient to determine which computations are performed by the brain during language comprehension. In the present study, we are interested in the time course of computations underlying phonological analysis during sentence comprehension. Using representational similarity analysis (RSA; Kriegeskorte et al., Front Syst Neurosci, 2008) and EEG, we will compare patterns of neural activity elicited by predictable and unpredictable word-initial phonemes to investigate different neurocomputational proposals. While sharpening proposals suggest the predictable speech sounds will have an enhanced or sharpened representation, prediction error proposals suggest that the brain computes the difference between the prediction and the input, thereby representing unpredictable information. Since the representational output of these computations should contain qualitatively different information, we expect that different patterns of neural activity should emerge corresponding to which computations are present. EEG data were collected from 70 Dutch participants at the Max Planck Institute for Psycholinguistics. Participants listened to highly predictive sentences (mean cloze = 0.92) that ended in either a predictable or unpredictable word. Unpredictable words mismatched with predicted words in both semantics and phonology. For example, predictable 'boeket' (bouquet) was replaced with unpredictable 'tonnetje' (barrel). Our analyses will investigate the correlation between observed representational dissimilarity matrices (RDMs), determined from neural responses to predictable and unpredictable word-initial speech sounds, and theoretically-motivated model RDMs, which describe the hypothetical representations proposed for various neural computations. We will use four model RDMs, corresponding to (1) representations of the heard phonemes; (2) representations of the predicted phonemes (e.g., Wang et al., eLife, 2018, observe anticipatory representations of predicted lexico-semantic information); (3) sharpening representations (i.e., a blend of the features of the predicted and heard phonemes); and (4) prediction error representations (i.e., the difference between the features of the predicted and heard phonemes). The temporal precision of EEG data allows us to test for different computations as speech unfolds. The performance of each model RDM over time will be determined by the strength of the correlation between the model RDMs and observed RDMs. Since previous studies using fMRI report findings that are consistent with either sharpening (e.g., Heilbron et al., Nat Commun, 2020) or prediction error (e.g., Blank & Davis, PloS Biol, 2016), we expect that we may observe neural responses consistent with all four model RDMs, but perhaps with different time courses.

Topic Areas: Phonology and Phonological Working Memory; Speech Perception

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Is neural entrainment language specific at 6 months of age? *Sandbox Series*

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Neural oscillations at multiple frequencies simultaneously entrain to the rhythms in the continuous speech signal (Giraud & Poeppel, 2012). Through neural entrainment, the human brain is allowed to segment speech into phrases, syllables, and phonemes (Meyer, 2017). Adults show stronger neural entrainment to their native speech than non-native speech (Pérez et al., 2015; Ding et al., 2016; Etard & Reichenbach, 2019), but native speech specialization through neural entrainment in infants is relatively unknown. Infants at birth have a coarse ability to discriminate between languages that differ greatly in rhythm, such as French from Russian (Mehler et al.,1988). From 4.5 months of age, they develop the ability to distinguish their native language even from a prosodically similar one (Bosch & Sebastián-Gallés, 1997; Nazzi et al., 2000). Later at 6 months, infants start showing the first signs of attunement to the native language (Werker & Tees,1984; Kuhl et al., 1992). Studying brain-to-stimulus coupling in 6-month-old infants, Barajas et al (2021) did not find differences in amplitude or phase tracking between native and non-native languages, but in their design, infants repeatedly listened to the same sentence from each language. In our project, we want to measure brain-to-stimulus coupling in 6-month-old infants listening to a variety of sentences. With this goal, we are analyzing the data collected by Peña et al (2010), where twenty-six 6-month-old infants listened to sentences from Spanish (native language), Italian, and Japanese, presented both forwards and backwards. All three languages differ in their segmental and phonotactic repertoires, but Spanish and Italian are prosodically similar as they are both syllable-timed languages, whereas Japanese is a mora-timed language (Ramus et al., 1999). Peña et al (2010) found that 6-month-old infants show stronger spectral power in gamma frequency for their native language than non-native languages regardless of rhythm. Our goal is to explore infants' neural entrainment to the prosodic contour of languages prosodically similar to and distant from their native language. We measure entrainment as the correlation between speech envelopes reconstructed from their EEG and the original speech envelopes (Vanthornhout et al., 2018), filtered below 8 Hz, to capture the prosodic cues in speech: both intonation and syllabic rhythm (Meyer, 2017). We have two potential outcomes regarding our hypotheses. 1) If the neural entrainment to speech in infants is native language specific, we expect to find higher entrainment to native language (Spanish) than to non-native languages (Italian and Japanese). 2) If it is rhythm specific, we expect to find similar neural entrainment to Spanish and Italian, and we expect neural entrainment to Japanese to be lower. We expect no differences between languages in the backward speech condition, as sentences presented in reverse lack the rhythmic information in speech (Ramus et al., 2000).

Topic Areas: Speech Perception; Development

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Differences in Processing of Voice Onset Time in Bilingual Italian-German Children and Monolingual German controls. *Sandbox Series*

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Exposure to more than one language influences children's phonemic development (e.g. Kehoe & Kannathasan, 2021). Bilingual children's neural commitment to their two languages and hence their phoneme processing abilities vary in accordance with the relative amount of exposure to each language (Sebastián-Gallés & Bosch, 2002). Mismatch Responses (MMRs) are known to index automatic neural discrimination of speech contrasts (Yu et al., 2020). By combining neurophysiological and behavioral measures we examine the perception and production of Voice Onset Time (VOT) in the two languages of bilingual Italian-German speaking five-year-olds and a control group of monolingual German peers. VOT is a salient phonological feature in many languages that has often been used to study the impact of bilingualism on speech production and perception as its specific realization differs across languages (e.g. Kupisch & Lleó, 2017; Lein, Kupisch, & van de Weijer, 2015). German and Italian differ in that respect, with German contrasting short lag VOT with long lag VOT and Italian contrasting short lag VOT with voicing lead. Twenty-two five-year-olds (12 monolingual German and 10 bilingual Italian-German children) were tested using the neurophysiological potential Mismatch Response (MMR) to speech-sound contrasts. Stimuli consisted of bilabial stop consonants. The short lag stop (0 ms VOT), common to both languages was used as the standard. Four deviant VOTs were selected: 92 ms (ASPeasy) and 36 ms (ASPdifficult) lag for German; and 112 ms (PREVeasy) and 36 ms (PREVdifficult) lead for Italian. MMRs were derived by subtracting the standard from each deviant (Yu et al., 2020). A picture-naming task was used to elicit productions of 10 initial-stop words in each of a child's language/s. The acoustic measurements were undertaken in Praat (Boersma & Weenink, 2013). Language background was assessed using a parent questionnaire. MMRs were greater for the easy compared to the difficult condition. Preliminary analysis revealed that both groups of children showed MMRs of an initial positivity followed by a negativity, similar to Shafer and colleagues (2010). Mixed ANOVAs revealed a significant group difference for ASPeasy ($p=0.017$). The monolinguals showed a greater positive MMR at 100-150ms. For ASPdifficult a significantly greater negative MMR ($p=0.013$) was observed for the monolingual group around 200-250ms. No group difference was observed for neither of the prevoiced stimuli. Examination of the means show that generally bilinguals showed a greater negativity compared to the monolinguals. A repeated measures ANOVA revealed that bilinguals produced significantly distinct VOT categories in their two languages ($p=0.001$). Post hoc tests revealed that bilinguals, in fact, had formed a total of four distinct VOT categories. Our data show that a greater acoustic difference between the standard and the deviant enhances the MMR. Further, our findings are consistent with Yu and colleagues (2020) suggesting that bilinguals may pay more attention to the speech signal thereby enhancing their negative MMR. It an unexpected result that we did not find a significant advantage for the bilingual children when processing the prevoiced contrast. Explanations for this will be discussed within the context of the children's language background and their VOT production.

Topic Areas: Speech Perception; Multilingualism

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Formant-invariant voice representations are pre-attentively formed from constantly varying speech and non-speech stimuli *Sandbox Series*

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Despite being integrally processed, phonological and talker-related information can be selectively extracted from speech for different communicative goals. Yet, as both dimensions are characterized by considerable amount of physical variability, listeners may build information-specific representations which are invariant to changes along the irrelevant dimension. Previous studies showed that listeners pre-attentively form abstract phoneme representations irrespectively of constant changes in the talkers' voices. The aim of the present EEG study was to determine if listeners can also form abstract voice representations while ignoring constantly changing phonological information and if they can use the output of this mechanism to facilitate volitional voice change detection. Secondly, the study aimed at understanding whether the use of such abstraction mechanism is restricted to the speech domain, or if it could be deployed also in non-speech contexts. Fifteen Italian native speakers were involved in an EEG experiment which included a passive and an active oddball task, each featuring a speech and a non-speech condition. In the speech condition, participants heard constantly changing vowels produced by a male speaker as standard stimuli which were infrequently replaced by vowels uttered by a female speaker with a higher pitch. In the non-speech condition, participants heard the rotated-speech version of the stimuli, synthesized by rotating the spectrum along a pivot frequency. This manipulation results in a power exchange between high and low frequencies, disrupting the previously meaningful formant structure. Results showed that, in the passive task, the Mismatch Negativity (MMN) was elicited after the presentation of the deviant voice both for the speech and the non-speech condition. The elicitation of this component in both conditions signaled that listeners could successfully group together different stimuli into a formant-invariant voice representation. This suggests that listeners can represent abstract regularities along voice-dependent dimensions in auditory streams irrespectively of the presence of meaningful linguistic information. After the MMN, a stronger Late Discriminative Negativity for the speech condition was found, possibly indicating that phonological details could be included in voice representations but only later in time. In the active task, responses were faster and more accurate in the speech compared to the non-speech condition. Additionally, for the speech condition, the detection of the deviant stimuli highlighted an enhanced P3b amplitude. This suggests that when pre-attentively formed voice representations include familiar phonological information, pitch detection is facilitated. This facilitation in the speech condition was also testified by a stronger synchronization in the theta band (4-7 Hz), potentially pointing towards differences in encoding/retrieval processes, and by a reduced desynchronization in the beta band (13-30 Hz), suggesting that deviant events with a familiar formant structure induced an attenuated disruption of the previously formed representation. Taken together, the results show that whereas at a pre-attentive level the cognitive system can track pitch regularities while abstracting away from constantly changing formant frequency values both in speech and in non-speech, at a volitional level the use of such information is facilitated for speech sounds given the familiarity of listeners with meaningful formant structures.

Topic Areas: Speech Perception; Perception: Auditory

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Homophonic speech sequences in French: The role of acoustic and contextual cues for disambiguation *Sandbox Series*

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Due to the lack of clear word boundaries in spoken language, listeners use tacit knowledge to segment speech. Speech segmentation is proven to be affected by the listeners' sensitivity to acoustic cues, subphonemic properties (Davis et al. 2002), and contextual information (Norris,1994). Fine acoustic details can influence word boundaries' perception (Friederici & Wessels,1993). In French, Welby (2003) and Spinelli et al. (2007) showed that listeners used fundamental frequency rises to detect content word beginnings. The use of low-level features to segment speech is particularly salient when contextual information is insufficient (Mattys et al. 2005). Yet, little is known about the cognitive load of exposure to acoustic information not congruent with sentential information. In our study, we investigated the cognitive cost of segmenting ambiguous speech units when context is provided and explored whether and how fine-grained acoustic details can affect semantic processing. We recorded French sentences containing homophonic sequences of article+noun allowing for different segmentations, such as "l'affiche" ("the poster") and "la fiche" ("the sheet"), both pronounced /lɑfiʃ/. Homophonic sequences were presented in 3 different context conditions: congruent, incongruent, and control. Context conditions were generated by two acoustic manipulations to avoid acoustic differences: cross-splicing yielded contexts that were not congruent with the homophonic sequence included ("La secrétaire médicale a perdu l'affiche du patient", "The medical secretary lost the patient's poster"); congruent sentences were generated after an identity-splicing including the other homophone candidate, here "la fiche". Control sentences contained a non-congruent, non-homophonic sequence ("Le cordonnier répare la tendresse du directeur", "The shoemaker repairs the tenderness of the director"). In a first experiment, participants were presented with a semantic judgment task focusing on the meaning of sentences, mainly serving as attentional control. To assess semantic processing differences across context conditions, analyses were focused on the N400 Event-Related Potential (ERP) component. Topographic analyses revealed the presence of an N400-like component in central to parietal sides. Control contexts were significantly more negative than both congruent and incongruent ones, while these two conditions did not differ. Fine-grained acoustic information does not seem to modulate semantic integration when exposed to informative-enough contexts. In a second experiment, we assessed the role of attention to acoustic properties during speech processing. Responses and reaction times were collected during a recognition task, in addition to ERPs. Each auditory sentence was matched with three target conditions: i) a word that appeared in the sentence, ii) a word that was absent, iii) for sentences with a homophonic sequence, the word corresponding to the sequence presented. Behavioral analyses using linear and generalized mixed-effects models revealed significant differences between context and target conditions. Participants responded significantly faster to homophonic targets after congruent contexts than after incongruent contexts and more errors were made to homophone targets compared to other target conditions. Preliminary ERP and permutation analyses showed a modulation of the N400 amplitude by context condition, supporting behavioral results. Top-down processes seem to influence speech segmentation when no attention is paid to linguistic properties, whereas bottom-up processes might influence perception when attention is directed to words.

Topic Areas: Speech Perception; Perception: Auditory

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Do sentences modulate the low-frequency neural response to words? *Sandbox Series*

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Listeners have the remarkable ability to combine acoustic information from speech with abstract linguistic knowledge, resulting in a structured representation of intended meaning. Recent work in psycho- and neurolinguistics has revealed signatures of this process in the brain: in the delta band (≤4Hz) – the timescale of occurrence of words/phrases – speech tracking is affected if the linguistic structure or content is manipulated (Blanco-Elorrieta et al., 2020; Molinaro & Lizarazu, 2018; Kaufeld et al., 2020). In the theta band (4-8 Hz) – the timescale of syllables – speech tracking is affected by modifications of the acoustic signal (Etard & Reichenbach, 2019; Peelle, Gross & Davis, 2012; Doelling et al., 2014). Furthermore, lexical features also drive low-frequency neural responses (e.g., Weissbart et al., 2019; Brodbeck et al., 2018; Broderick et al., 2018), but it is not yet clear how linguistic structure affects these. Here we ask therefore whether and how the neural response to spoken words in the delta and theta bands changes when words appear in sentences or word lists. We analyze published MEG data from 102 participants listening to Dutch sentences (9-15 words, various syntactic structures) and word lists: scrambled sentences (Schoffelen et al., 2019). We model the source-localized neural response to words using temporal response functions (TRFs) and compare these between the conditions. This approach allows for the estimation of effects above and beyond differences in the acoustic signal. To this end, we add speech envelope- and word onset-features to all models. The feature we use as a proxy for lexical information is word frequency, a crucially unigram feature. To isolate the sentence effect from sequential predictability effects, we include estimates of surprisal and entropy. Because these estimates contain frequency information, including them in the models offers the strongest test of sentence effects on the neural response to word frequency. Using cross-validation, we estimate TRFs at lags from -200ms to 800ms, and quantify how well they reconstruct the neural signal. On the basis of analysis-by-synthesis accounts of language comprehension (Martin, 2016; 2020; Poeppel & Monahan, 2011), we expect the neural response to word frequency to be modulated by the words' involvement in sentences. Specifically, we hypothesize that word frequency modulates the neural response in both conditions in temporal and left inferior parietal areas (Hagoort, 2013). In the sentences, however, this modulation should be more pronounced and spatially more widespread as a result of propagation of lexical information when this becomes included in larger structures (Martin, 2020). The spread is likely visible in the left inferior frontal gyrus (Hagoort, 2013). We expect this pattern in the delta band. In theta, we might see a neural response to words due to supply of syllabic information (Brown, Tanenhaus & Dilley, 2021), but the response may not differ between conditions. The results of this study will speak to how the neural representation of words is affected by structural embedding, and as such provides insight into how the brain instantiates compositionality in language (Martin, 2016; 2020).

Topic Areas: Speech Perception; Syntax

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The Protecting Effect of Singing on Communication and Cognition in Aging: Behavioural and Brain-Imaging Data Analysis *Sandbox Series*

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Introduction. Voice and speech production can deteriorate significantly with age [1,2], with impact on communication-mediated activities and social participation. Though the exact cause of these dysfunctions remains unknown, previous studies have shown functional and structural changes, including in the insula, premotor cortex and supratemporal cortex, that correlate with changes in speech production performance, suggesting that changes to speech functions have a central origin. Normal and pathological aging are also associated with decreased resting-state functional connectivity in multiple networks, but the impact of these decline on speech skills, if any, is unknown. Despite important decline, the adult human brain retains a remarkable capacity to modify its organization in an enduring manner throughout the lifespan, as a correlate of skill acquisition, a phenomenon known as experience-dependent brain plasticity. Yet, very little is known about how age and experience can have a transformative effect on the neural speech system. One promising avenue of research focuses on the mediating impact of singing on voice and articulation decline in aging, through neuroplastic changes. Understanding the mechanism of action of singing could contribute to the development of new neurorehabilitation interventions for communication difficulties in aging. The goal of our study is to evaluate the effects of brain aging on voice and speech production in aging singers and non-singers. The specific aim is (1) to use magnetic resonance imaging to unravel resting-state connectivity differences between singers and non-singers to understand underlying plasticity mechanisms and (2) examine how potential differences in brain connectivity relate to age-related decline in voice production and articulation. The main hypothesis is that singing will have a positive impact on the relationship of age to voice production and articulation, meaning that singing will attenuate the effect of aging on communication through its impact on resting-state connectivity. Methods. 41 singers aged 22 to 87 years (mean 55 ± 19 years; 27 females) and 43 non-singers aged 20 to 86 years (54 ± 20 years; 22 females) were recruited in Québec City. The singers had 2 to 62 years of continuous choral singing experience (mean 17.68 ± 14.14 years). Participants completed speech tasks including passage reading, vowel production and nonword repetition. Participants were scanned on a 3T MRI scanner (Philips Achieva). T1-weighted images (1mm3) and resting-state data (TR/TE = 2500/30 ms, 200 volumes, 3 mm3). Cardiac beat and respiration were measured during the sequence. To address Objective 1, the resting-state data will be pre-processed to remove motion, breathing and cardiac oscillations. Next, the resting-state fMRI data will be analyzed using a seed-based approach. The primary seed will be selected based on results from prior speech experiments in our lab. All connected seeds will be mapped on a Functional Connectivity Map for singers and non-singers respectively. The resting-state networks will also be examined using a whole-brain ICA approach. We expect to find the difference of resting-state networks between singers and non-singers. Data collection is terminated but analyses have recently begun. Preliminary results will be available at the meeting. Reference [1] Tremblay, 2016. BrainStructFunct [2] Tremblay, 2018. PsycholAging

Topic Areas: Perception: Speech Perception and Audiovisual Integration; Speech Perception

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Investigating neural representations of voice identities using representational similarity analysis *Sandbox Series*

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Voices belonging to different speakers are individualised based on anatomical and social factors, such as vocal tract size and accent (Scott & McGettigan, 2015). However, within-speaker voice properties can also be highly variable, depending on both what is said and how it is said (Lavan et al., 2019). Therefore, to effectively encode different vocal identities, listeners must be able to both tell speakers apart and 'tell speakers together' (Burton 2013; Lavan et al., 2019). We will use representational similarity analysis to investigate whether listeners form distinct neural representations based on the voice identities of different speakers. Representational similarity analysis is based on the premise that stimuli that share similar representations elicit similar neural response patterns in the relevant region (Kriegeskorte et al., 2008). Therefore, we can probe the neural bases of vocal identity by comparing the similarity of neural responses to naturalistic speech both across- and within- speaker identities. We will analyse neural responses from the Naturalistic Neuroimaging Database (Aliko et al. 2020), an open-access fMRI dataset of 84 participants watching feature-length movies. We have constructed hypothetical representational dissimilarity matrices (RDMs), which predict (dis)similarities in neural activity between different speech tokens from the movie "500 Days of Summer". Each RDM predicts dissimilarities based on different aspects of speaker identity. The first RDM includes within-speaker comparisons, and predicts that neural responses to the same speaker will become more similar as listeners gain familiarity during the movie. The second RDM includes across-speaker comparisons, and predicts differences in neural responses based on the broad demographics of speaker sex. The final RDM includes across- and with- speaker comparisons to represent similarities based on individual speaker identity: neural responses to speech tokens from the same speaker are predicted to be similar, and responses to speech tokens from different speakers are predicted to be dissimilar. We will combine a searchlight and region-of-interest approach to record actual observed neural dissimilarities between speech tokens at each voxel. Searchlight analyses will be conducted within bilateral superior temporal gyrus and superior temporal sulcus, following previous work that has shown voice-sensitive neural activation within these areas (Tsantani et al., 2019). Each hypothetical RDM will then be correlated with observed neural dissimilarity at each voxel within these regions. Correlations between hypothetical RDMs and observed neural dissimilarity between speech tokens should reveal potential sensitivities to different aspects of vocal identity in the relevant brain regions. On completion of this work, we hope to better understand the neural representations that contribute to telling voices together and telling voices apart. Further, we can assess the real-world validity of previous findings, by investigating whether neural regions previously associated with voice identity processing in experimental paradigms show consistent activation in response to naturalistic stimuli.

Topic Areas: Speech Perception; Perception: Auditory

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Relationship between persistence and speech intelligibility of time-compressed speech *Sandbox Series*

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Older adults report greater listening effort than younger adults, especially for degraded speech [1]. Individuals facing effortful listening during time-compressed (i.e., rapid) speech may resort to persistence, the ability to exert effort to overcome difficulty [2], as a top-down processing strategy. Indeed, persistence predicts neural activity in the dorsal anterior cingulate cortex that detects and overcomes errors when recognizing speech in background noise [2]. Pupil dilation is an objective measure that can track the listening effort associated with speech intelligibility for young, middle-aged, and older adults [3-4]. Because the pupil response reflects cortical inputs to the autonomic nervous system, increases in pupil dilation indirectly measure the attention system's response to increasing task demands [5]. The present study examines how persistence affects accuracy and pupil dilation (i.e., listening effort) during recognition of time-compressed speech in healthy younger and older adults. We report results from 11 younger adults aged 18-35 years, as data collection for older adults was paused due to Covid-19. Participants completed background questionnaires to obtain demographic information and were screened for mild cognitive impairment. They completed verbal working memory and processing speed assessments, and the Wisconsin Card Sorting Task-64 [6] to assess individual differences in shifting and persistence. Participants underwent a vision screening and a standard audiological assessment. Then, they completed a speech recognition task. On each of 36 trials, participants listened to and repeated 4 words presented at time-compression rates of 0% (normal speech), 30% (rapid speech), and 60% (very rapid speech). Pupil diameter was measured during listening using Micromedical Video Nystagmography goggles, in an illumination-controlled environment. Analyses examined the peak pupil diameter in 1-second increments from speech onset. Recognition accuracy was 8% higher for 0%-compressed versus 30%-compressed words ($t(10) = 4.98$, $p < .01$) and 5% higher for 30%-compressed versus 60%-compressed words ($t(10) = 3.07$, $p = .01$). Compression significantly affected pupil dilation ($F(1.03, 8.22) = 6.86$, $p = .03$) and this effect interacted significantly with persistence ($F(1.03, 8.22) = 8.18$, $p = .02$) and time window ($F(1.44, 11.50) = 5.47$, $p = .03$). In individuals with higher persistence, pupil dilation increased linearly from 0% to 30% to 60% compression, with peak dilation occurring 2-3 seconds after trial onset. In contrast, individuals with lower persistence exhibited maximal pupil dilation in the 30% condition, peaking 4-5 seconds after trial onset. Results suggest that, even among healthy young adults, persistence affects the extent to which individuals continue to exert effort as speech rate increases. Those with lower persistence exhibit a drop-off in a physiological index of listening effort as speech rate rises, suggesting that these individuals may be vulnerable to speech comprehension deficits. [1] Anderson Gosselin & Gangé. J Speech Lang Hear Res. 2011;54:944-58. [2] Teubner-Rhodes et al. Neuropsychologia. 2017;102:95-108. [3] Kuchinsky SE et al. Psychophysiology. 2013;50(1):23-34. [4] Wingfield A. Ear Hear. 2016;Suppl1:35S-43S. [5] Zekveld et al. Ear Hear. 2010;31:480-90. [6] Kongs et al. Wisconsin Card Sorting Test—64 card version. Lutz (FL): PAR Inc.; 2000.

Topic Areas: Speech Perception; Control, Selection, and Executive Processes

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Divide and Conquer: Own-Name detection during ecological concurrent speech processing *Sandbox Series*

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A well-known phenomenon is the experience of noticing one's own name spoken by an otherwise unattended speaker. This "Cocktail Party Effect" has long fueled debates regarding the extent to which so-called "unattended" speech is processed. However, it is difficult to reliably gauge the prevalence of this effect since most studies use selective attention tasks, where detection of unattended words is assessed only indirectly. For example, using subject-report measures, only ~33% of participants report noticing their name. This critically limits the ability to draw theoretical inferences regarding the depth of processing applied to concurrent speech. To circumvent this methodological limitation, here we address this question from a different perspective by employing a Divided attention task. We ask two specific questions: What is the capacity for detecting individual words from background speech, while listeners are primarily engaged in processing a natural speech narrative? And, does detecting one's own name enjoy a unique status? Participants were presented with two concurrent speech streams: A Narrative stream, which was a natural recording of continuous speech, and a Starbucks stream, that simulated a barista calling out orders, including names and food items. Participants were instructed to listen to the Narrative and answer subsequent comprehension questions. In addition, they were also required to monitor the Starbucks stream and detect a specific target-name, which could be either their own name or a different control name. Neural activity was measured using EEG during the task, as well as changes in skin-conductance levels (GSR). Accuracy in both tasks was high, with target-detection rates near ceiling (>90%). Moreover, there were no apparent behavioral tradeoffs between performance on the two tasks. This suggests that individuals have a relatively good capacity for monitoring background speech and detecting specific words, without compromising comprehension of a main narrative. When comparing detection rates of the two different targets, performance was significantly better for detecting one's own name vs. a control name. This effect was accompanied by increased neural responses (in a time-window corresponding to the P600 ERP-component) as well as heightened GSR responses to one's own name. These results provide new perspectives regarding the capacity for processing concurrent speech and indicate that it is possible to monitor background speech for specific information while also fully processing continuous speech. This is in line with proposed 'late-selection' models and invites fine-tuning of theoretical accounts of 'bottlenecks' for processing concurrent speech. In addition, the clear advantage for detecting one's own name is in line with previous findings, indicating an advantage for processing personally-meaningful information in noisy, multi-speaker contexts.

Topic Areas: Speech Perception; Control, Selection, and Executive Processes

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Statistical learning modulation through the variation of stimulus rhythmic structure. *Sandbox Series*

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Statistical learning is the ability to extract regularities present in the environment. In the context of speech, statistical learning is generally regarded as one of the cognitive processes that supports early lexical and morphological rules acquisition. This phenomenon has been widely studied in the past decades by means of the Statistical Word Form Learning (SWFL) protocol, where participants are exposed to a learning phase where four tri-syllabic pseudo-words are presented in a continuous stream and learning is assessed post exposure. One of the stable features of studies employing this protocol is the isochronous nature of the stimulus, i.e., each syllable in the stream has the same duration. Although it has been shown that natural speech possesses some temporal regularity, with a mean syllabic rate across languages between 2 to 8 Hz, it is far from being perfectly rhythmic. In order to assess the ecological validity of SWFL, therefore, it is crucial to explore its robustness against variations in the temporal structure of the stimulus. In this work, we study how disrupting the rhythmic characteristics of the auditory stimulus modulates SWL performance. One of the requirements for detecting variations in SWFL performance is to design stimuli with a high learning rate. Thus, our first goal was to generate and validate 4 different isochronous pseudo-languages optimized to evaluate Spanish speaking participants. To construct the 4 tri-syllabic pseudo-words comprising each pseudo-language, we controlled the syllables' position frequency according to the statistical properties of the Spanish language using the Syllabarium database. For the stimuli synthesis, the two methods typically used in the literature were also compared: (i) generating a co-articulated stream using Mbrola against (ii) concatenating isolated synthesized syllables. Significant perceptual differences were observed, favoring Mbrola, which was then selected to construct the final stimuli set. Finally, we obtained four pseudo-languages with significantly high learning rates - approximately 75% of correct answers. Each of the pseudo-languages was then resynthesized in a non-synchronous version: the duration of each syllable composing the continuous flow of pseudo-words was randomly selected from a flat distribution of syllabic frequencies between 2 and 8 Hz. The main experimental design consists of the presentation of four blocks; each with one of the previously constructed pseudo-language presented either synchronously (all syllables last 250 ms) or non-synchronously. Preliminary data shows learning significantly above chance for both conditions, with an enhancement in the synchronous one. Further work will assess the functional relationship between learning performance and stepwise decrements in the temporal regularities of the stimulus as well as with different values of syllable rate for isochronous stimuli.

Topic Areas: Speech Perception; Perception: Auditory

Slide Slam Session D

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Neural Correlates of Picture Naming versus Definitional Naming

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Anomia, a disruption in naming, is one of the most common language symptoms following brain injury. Naming is often assessed with picture naming tests such as the Boston Naming Test (BNT). More recently, alternative naming tasks have been developed that require patients to name an item in response to a brief definition (e.g., What is the name of the part of your shirt that goes around your neck?). Such definitional naming tasks have the advantage of avoiding potential confounds in picture naming, such as poor performance due to visual processing deficits. It is unclear, however, to what extent picture naming and definitional naming tap the same cognitive and neural mechanisms. In the current study, we evaluated a group of chronic left hemisphere stroke patients on a newly developed definitional naming test, the Verbal Naming Test (VNT; Yochim et al., 2015, 2019). Our goals were: 1) to characterize stroke patient performance on this new naming task, 2) to identify its neural underpinnings, and 3) to compare the VNT to traditional tasks of visual naming. Stroke patients with a single left hemisphere stroke (n = 19) were administered the VNT, the Boston Naming Test-15 (BNT-15), and the Western Aphasia Battery (WAB) Object Naming subtest in different sessions. To determine the anatomic correlates of naming, we related patients' naming scores to ROIs using quasi-logistic regression analyses with lesion volume, months post-stroke, and aphasia severity as covariates. Due to the small number of patients, the analysis was focused on ROIs in the left temporal lobe that have been previously implicated in naming: the superior temporal gyrus, middle temporal gyrus, and inferior temporal gyrus. These regions were further subdivided into an anterior and posterior half for each gyrus. Mean performance on the VNT without cueing was 29.4 items out of 50 (SD = 18.2, range: 0-50), and with phonemic cueing was 34.7 items out of 50 (SD = 19.3, range: 0-50). VNT performance was highly correlated with the BNT-15, r(16) = .94 and with WAB Object Naming, r(17) = .87. We found that both definitional and picture/object naming tasks were most strongly associated with the left middle temporal gyrus. We also found that all tasks were more strongly associated with posterior temporal cortex than anterior temporal cortex. These findings are consistent with our previous findings in a larger sample of stroke patients showing that left mid-posterior middle temporal cortex and underlying white matter was most critical to picture naming. However, other findings have suggested that left anterior, and sometimes ventral, temporal cortex, are most strongly associated with naming, particularly in degenerative cases. This association with anterior temporal cortex has also been noted for definitional naming tasks in previous studies. Additional, larger-scale studies with more comprehensive lesion coverage are needed to further investigate these naming dissociations in both stroke-related and degenerative disease.

Topic Areas: Disorders: Acquired; Language Production

Slide Slam D2 Play Video

Brain regions that support accurate speech production after damage to Broca’s area

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Broca’s area in the posterior half of the left inferior frontal gyrus has traditionally been considered an important node in the speech production network. Nevertheless, recovery of speech production has been reported, to different degrees, within a few months of damage to Broca’s area. Here we investigated the brain activation patterns that underlie accurate speech production following stroke damage to Broca’s area. By combining functional MRI and 13 tasks that place varying demands on speech production, brain activation was compared in (i) seven patients of interest with damage to Broca’s area, (ii) 55 neurologically-intact controls and (iii) 28 patient controls with left-hemisphere damage that spared Broca’s area. When producing accurate overt speech responses, the patients with damage to Broca’s area activated a substantial portion of the normal bilaterally distributed system. Within this system, there was a lesion-site-dependent effect in a specific part of the right cerebellar Crus I where activation was significantly higher in the patients with damage to Broca’s area compared to both neurologically-intact and patient controls. In addition, activation in the right pars opercularis was significantly higher in the patients with damage to Broca’s area relative to neurologically-intact controls but not patient controls. By further examining how right Crus I and right pars opercularis responded across a range of conditions in the neurologically-intact controls, we suggest that these regions play distinct roles in domain-general cognitive control. Finally, we show that enhanced activation in the right pars opercularis cannot be explained by release from an inhibitory relationship with Broca’s area (i.e. dis-inhibition) because right pars opercularis activation was positively related to left pars opercularis activation in the neurologically-intact controls. Our findings motivate and guide future studies to investigate (a) how exactly right Crus I and right pars opercularis support accurate speech production after damage to Broca’s area and (b) whether non-invasive neurostimulation to one or both of these regions boosts speech production recovery after damage to Broca’s area.

Topic Areas: Disorders: Acquired; Language Production

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A New Approach for Identifying Functionally Compromised Tissue in Individuals with Chronic Aphasia

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Introduction: Individuals with chronic aphasia (IWA) exhibit variable patterns of language impairment, which makes it difficult to identify structure-function brain relationships[1,2]. This variability may be due to underlying alterations in brain function. Prior research has demonstrated that IWA have reduced cerebral blood flow (CBF; hypoperfusion) in areas of the brain that are structurally intact[3,4]. However, across these studies there is little consensus on how to best define hypoperfusion. Though standard CBF threshold values exist (healthy≥50mL/100g/min, hypoperfused=12-20mL/100g/min, necrotic≤12mL/100g/min), they do not fully capture tissue functionality in IWA[5-7]. Further, group-level analyses may overshadow important individual differences. In this exploratory study, we defined an individualized metric for hypoperfusion and used it (vs. standard approaches) to investigate (1) when perilesional tissue (often functionally compromised) returned to “normal” CBF levels and (2) how well our metric correlated with auditory comprehension. Methods: Participants included 6 monolingual, right-handed (premorbid), chronic (>1 year) IWA who had a single, unilateral, left hemisphere stroke. Aphasia subtype and severity were based on the Boston Diagnostic Aphasia Examination-3 and the Western Aphasia Battery-Revised[8-9]. Auditory comprehension was measured through the comprehension subtests of these assessments. Neuroimaging Procedures: Anatomical and resting state CBF data were acquired using a 3T-GE scanner (pre-processing information can be found in Abbott et al. 2021[10]). All scans were co-registered and labeled using the Automated Anatomical Labeling Atlas[11]. To systematically define perilesional tissue, we created four 3mm perilesional bands (0-3mm, 3-6mm, 6-9mm, 9-12mm). Analyses: Group- and individual-level analyses were performed to demonstrate the importance of an individualized approach. Here, we defined “normal” brain tissue based on each participant’s right hemisphere average CBF (CBFRH) and “functionally compromised” tissue as anything less than 1.5 standard deviations below CBFRH. Hypoperfusion in LH-perilesional bands and specific regions of interest (ROIs) were identified to explore the relationship between hypoperfusion and language behavior. Results: Our individualized approach was more sensitive to differences in tissue functionality for each participant. While the group-level analysis showed no difference in the 0-3mm band from the calculated hypoperfusion threshold ($t(5)=-1.18, p=0.15$), individual-level analyses revealed additional information; there were differences if and when CBF values returned to “normal” in the remaining three bands. Our individualized approach also picked up on hypoperfusion in ROIs that remained structurally intact, suggesting that our metric is more sensitive to individual patterns of brain function. Correlations between the two CBF metrics (standard/individual) and language behavior revealed a correlation between auditory comprehension and multiple temporal regions, which did not exist with standard thresholding. These results suggests that our individualized metric may better identify functionally compromised tissue on an individual basis. Conclusions: We propose a new approach for measuring functionally compromised brain tissue in IWA. Standard cut-off values and group-level analyses often over- or under-estimate tissue functionality in IWA. These results underscore the necessity of considering not just the structural integrity of brain regions but also the functional integrity when investigating structure-function relationships. By adding in measures of functional integrity, researchers may be able to better account for some of the variability demonstrated by IWA.

Topic Areas: Disorders: Acquired; Methods

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Hub functional connectivity differences in the dual-stream language network in stroke survivors with aphasia: a resting-state fMRI study

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The dual-stream model of speech processing has become a prevailing framework to explore the critical neural substrates for speech and language recovery in stroke survivors with aphasia. Yet, very little is known regarding the network-level organization of the dual-stream model's regions, and how this organization may be disrupted in aphasia. Previous work indicates that resting-state functional connectivity is a promising tool to understand the network-level properties of the dual-stream regions, yet our previous work indicates that functional connectivity across the entire dual-stream network does not on average differ in stroke survivors with aphasia versus controls, or as a function of severity of language impairments. But, graph-theoretical approaches may be a more sensitive method to better understand how dual-stream network organization is disrupted in individuals with aphasia. Thus, in the current study, 28 neurotypical adults (20-79 years, native English-speaking, right-handed) and 28 left hemisphere stroke survivors (35-78 years, native English-speaking, right-handed), underwent resting-state functional MRI and structural MRI. Speech and language abilities of the stroke survivors were assessed using the Western Aphasia Battery. SPM12 and the Brain Connectivity Toolbox were used to calculate mean functional connectivity measures for 14 dorsal stream and 18 ventral stream nodes as identified by previous task-based functional MRI studies (Labache et al., 2019). In-house Matlab and R scripts then were used to identify hub nodes within the dual-stream network in the control subjects, by determining the shortest average path lengths using the small-world network assumption. This procedure identified the left precentral gyrus, left pars triangularis, bilateral posterior superior temporal sulcus, and bilateral middle temporal gyrus as the hub regions of the dual-stream network. The average functional connectivities of these hub nodes then were compared between the control and stroke survivor groups, and multiple regression models were used to predict each stroke survivor's performance on naming, auditory comprehension, spontaneous speech rate and repetition measures. The hub connections within the left dorsal stream and the connections between the hubs of the left dorsal and ventral streams were found to be significantly lower in the stroke survivor group compared to the controls. The regression models, after controlling for age, gender, education, and lesion size, found the following: functional connectivity of left dorsal-ventral hubs was a significant predictor for spontaneous speech rate, left dorsal and bilateral ventral hub connectivities were the significant predictors of repetition, and bilateral ventral and right dorsal-ventral were the significant predictors of naming. Overall, our results suggest that graph theory, and particularly examining the integrity and functionality of hub regions, may be particularly valuable in characterizing the critical disruptions to the dual-stream network in left-hemisphere stroke survivors with aphasia.

Topic Areas: Disorders: Acquired; Speech Perception

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The critical role of phonology in sentence-level writing and reading: Evidence from aphasia, alexia, and agraphia

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INTRODUCTION: Phonological alexia and agraphia are well-described syndromes reflecting damage to sublexical phonology-orthography correspondences. The hallmark features of poor nonword reading and spelling are associated with damage to left perisylvian cortical networks; however, practical implications of phonological impairment have received limited attention. Friedman (1996) observed disproportionate text-level reading errors on grammatical words and morphological markers in individuals with phonological alexia. Similarly, Beeson and colleagues (2018) documented effects on sentence-level writing, suggesting that phonological text alexia and phonological text agraphia are complementary disorders affecting everyday written language skills in those with acquired phonological impairment. Here, we tested the hypothesis that phonological skills would predict sentence-level reading and writing abilities in a heterogeneous cohort with damage to the left perisylvian language network (i.e., the dorsal pathway). METHODS: We evaluated data from a comprehensive language assessment from 41 individuals with acquired aphasia, alexia, and agraphia due to damage in left perisylvian cortical regions. There was a range of aphasia severity (16.7-96.4 AQ) and significant impairment of central linguistic skills (semantics and phonology) in relation to an age-education matched control group (n = 49). Speech production and handwriting were also impaired but adequate for intelligible/legible output. Composite scores were derived for: Semantic knowledge; Phonological awareness/manipulation skills; Speech production ability estimated from spoken repetition of words/nonwords; and Handwriting ability estimated from allographic conversion task (transcoding letters from upper-to-lowercase and vice versa). To examine text-level written language, we analyzed written picture descriptions of the picnic scene from the Western Aphasia Battery from all those with aphasia. Oral reading was evaluated in a subset of 20 individuals using a 100-word passage. Separate regression models were computed to examine the following dependent measures: Written picture description--Content information units (CIUs); Informativeness (CIUs/total words); Efficiency (CIUs/minute); and Proportion of grammatically well-formed and complete sentences // Oral reading--Total number of errors (deviations from the printed word); Reading errors on function words and morphological markers; and Reading errors on open class words. RESULTS: Individuals with aphasia were significantly impaired on all measures of sentence-level writing and reading. For written narratives, phonological skill consistently emerged as a significant independent predictor of all four dependent measures (CIUs [β=.460, p=.003], informativeness [β=.385, p=.004], efficiency [β=.453, p=.008], and grammatical form [β=.568, p<.001]). Handwriting skills (allographic conversion) also contributed to written informativeness (β=.386, p=.002). With respect to reading, phonological skills were the only significant predictor of overall reading errors (β=-.552, p=.017) and errors on closed class words and morphological markers (β=-.546, p=.025). In contrast, reading accuracy of open class words was not predicted by phonological skills (β=-.429, p=.055). CONCLUSION: This study affirmed the critical contribution of phonological skills to sentence-level written language ability. In particular, phonological performance, as measured by phonological awareness and manipulation tasks, strongly predicted content, efficiency, informativeness, and grammatical form of written sentences. The effects of phonology on reading were less robust but were more critical than the status of semantic knowledge or speech production abilities. Overall, these findings are consistent with complaints from individuals with chronic aphasia regarding persistent written language difficulties.

Topic Areas: Disorders: Acquired; Writing and Spelling

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Phonology, Semantics, and Speech Production Abilities Predict Naming, Reading, and Spelling in Individuals with Aphasia/Alexia/Agraphia

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INTRODUCTION: It has been more than twenty years since the idea was put forth that acquired language impairment can be conceptualized as a reflection of interactive processing of primary systems (e.g., semantics, phonology, and visual processing), rather than a collection of task-specific difficulties with speaking, listening, reading, and writing. In this study, we re-visit the predictive value of a primary systems approach to characterize acquired language impairment in a cohort of individuals with damage to left perisylvian cortical regions. Distinct from previous research, we examined three language modalities (spoken naming, oral reading, written spelling) within one cohort taking into account peripheral abilities (e.g., speech production and handwriting). METHODS: We examined data from a comprehensive assessment of 47 individuals with demonstrated acquired language impairment (aphasia/alexia/agraphia) in relation to age-matched controls, determining the status of Central Language Processes: Phonological awareness/manipulation with words/nonwords including segmentation, deletion, blending, and substitution tasks; Semantic processing including Pyramids & Palm Trees (picture) and PALPA subtests for spoken-word to picture match, written-word to picture match, auditory synonym judgement. Peripheral Processes were tested using: Speech production estimated from word/nonword spoken repetition; Writing (letter selection and production) estimated using upper-lowercase transcoding. Dependent measures included: Boston Naming Test; Oral reading of single words; Written spelling of single words. Statistical analysis: Individual scores on the tasks probing central and peripheral skills were entered into factor analysis using varimax rotation. Resulting factor scores were entered into multiple regression analyses to examine the predictive value of factor scores on dependent measures. To support clinical application, performance on selected individual tests were also analyzed as proxy scores in place of factor scores. RESULTS: Principal component analysis yielded a four-factor solution accounting for 79% of the variance. Factors were easily identified as relating to phonological processing, semantic knowledge, speech production, and letter shape knowledge. Derived factor scores for each participant were entered into multiple regression models to predict oral naming, reading, and written spelling; letter-shape factor was added for writing only. Three factor scores (phonology, semantics, and speech production) accounted for 72.5%, 73.6%, and 61.1% of the variance in naming, oral reading, and single-word writing, respectively, and all made significant contributions to the model. Letter-shape knowledge was not a significant predictor of single word spelling. Individual test scores provided excellent proxy for the factor scores as follows: phoneme deletion for phonological skill, written word to picture matching for semantics, and repetition of single words for speech production. CONCLUSION: This study confirmed the strong predictive association between underlying phonological and semantic skills on naming, oral reading, and spelling, but also separated the contribution of speech production difficulties. For naming and oral reading, speech production abilities had a strong moderating effect on performance, but the status of central phonological abilities had a distinct and marked influence as well. Regarding written spelling, reliance on underlying phonological skills was even more marked. From a clinical perspective, these findings suggest that remediation of the core phonological impairment should be a focused component of treatment for spoken and written language.

Topic Areas: Disorders: Acquired; Writing and Spelling

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Quantitative assessment of pitch and rhythm production abilities in left hemisphere stroke survivors with and without aphasia: evidence for shared rhythm resources for speech and music

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Previous studies indicate that individuals with aphasia also may have difficulties with rhythm perception in music, suggesting a possible overlap of critical neural resources between speech and music perception for rhythm in the left hemisphere. However, there are comparatively few studies of music production or musical auditory-motor integration in individuals with aphasia, in part because objectively assessing the pitch and rhythmic abilities of individuals with post-stroke aphasia is difficult given the subjective nature of music ratings and the variety of possible error types. Thus, the purpose of the current study was: (1) to develop a quantitative, sensitive method of evaluating music repetition abilities in stroke survivors with aphasia and (2) to use this method to determine how music repetition accuracy in stroke survivors is related to their performance in speech auditory-motor tasks. Twenty-three chronic left-hemisphere stroke survivors with and without aphasia completed a music repetition task, and tasks known to engage speech auditory-motor integration (non-word repetition, verbal working memory span, difficult sentence comprehension). The music repetition task consisted of 10 novel piano melodies (five to eight piano notes long) presented three time each. Participants were asked to listen to each melody and then sing the melody. Praat software was used to extract fundamental frequency and duration of each note in each melody produced. We then calculated a correlation between fundamental frequencies of notes of the produced melody with those of the played target melody (i.e., a pitch score). We used a similar procedure to calculate a correlation between produced duration and the target duration (i.e., a rhythm score). As expected in a heterogenous sample of stroke survivors, there was considerable variability in performance on the music repetition task across the sample, but neither the length of the melody nor the repetition number significantly affected performance. Age and lesion size also were not significantly correlated with pitch or rhythm performance. Nonword repetition was significantly correlated with both rhythm ($p=0.05$) and pitch ($p=0.04$) performance. Rhythm accuracy, but not pitch accuracy, significantly correlated with working memory span performance ($p=0.01$) and approached significance with sentence comprehension performance ($p=0.06$). A larger sample of stroke survivors and a control group are needed to further investigate these relationships, but these initial results suggest that we have developed an effective method to objectively evaluate music repetition abilities in left hemisphere stroke survivors with and without aphasia. Our findings also suggest that a stroke survivor’s music repetition performance may be related to speech auditory-motor integration abilities (known to be engaged in speech repetition, verbal working memory, and sentence processing) via shared neural resources in the left hemisphere supporting sensorimotor integration of rhythm in both domains.

Topic Areas: Speech Motor Control; Disorders: Acquired

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Impairments of Working Memory in Parkinson's Disease: A Systematic Review

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Introduction. Amongst the non-motor symptoms of Parkinson's Disease (PD), cognitive decline is the most significant one due to its influence on quality of life for those affected individuals. Several cognitive functions can be implicated including executive function, long term memory, short term memory, processing speed, attention and ability to learn new things. The current review focuses on working memory (WM) decline in PD. The decline of WM is focused because it is a significant component of executive function and plays a role in new learning, language processing, problem solving and laying long term memories. These are critical functions which have implications for prognosis and diagnosis of cognitive decline in PD. The objective of this study is to review recent research on WM decline in individuals with PD. The findings will have clinical implications for predicting the prognosis in the PD population. Methods. The current study is a systematic review of articles from the past 20 years aiming to build a more recent review of literature. The following search engines were used: PubMed, Google Scholar, and The Interprofessional Health Sciences Library Database at Seton Hall University. A total of 28 articles were reviewed. The reviewed articles focused on investigating the nature of WM decline in PD patients and factors associated with the decline. The tasks used to investigate this were primarily varying span tasks included in a neuropsychological test battery. Results. From the 28 reviewed articles, it is evident that the nature of working memory impairment in this population is varying. A few trends in WM decline in PD population were recognized, the most significant ones are 1) the occurrence of spatial WM deficits (Alonso-Recio et al, 2010; Caminiti et al, 2015), 2) impairment of verbal WM (Fournet et al, 2000; Hochstadt et al, 2006; and Costa et al, 2010), 3) Verbal WM impairments were due to attention difficulties (Tamura et al, 2003), 4) WM deficits correlated with the storage deficits (Blatt et al, 2014), 5) deficits in maintenance within WM (Beato et al, 2008), 6) Visual WM deficits were due to reduced storage (Lee et al, 2010), and 7) temporary storage of irrelevant information in WM causing considerable interference. Additionally, studies have also reported on the diagnoses of depression and diminished quality of life in PD patients with WM impairments. Conclusion. Recent research confirms the occurrence of WM impairments in PD. The trends in WM decline in this population may be reflective of the co-occurring deficits of other cognitive functions as well as the stage of progression of the disease. Patients with PD suffer from loss of dopamine, so inhibitory processes needed for working memory may be affected. These observations carry a predictive value of the disease. WM decline in PD might result in language processing deficits. Higher-level language production and comprehension may become difficult for patients with PD. Future research may bring more clarity regarding subgroups of Parkinson's Disease patients and cognitive impairments, particularly working memory impairment.

Topic Areas: Control, Selection, and Executive Processes; Phonology and Phonological Working Memory

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A novel Brief Executive Language Screen (BELS) for propositional language

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Conversational speech occurs at the interface between language and other cognitive processes including executive functions. Aphasia assessment tools have typically focused on core language skills like naming and classical aphasia type and severity. We develop a novel Brief Executive Language Screen (BELS) that is designed to assess language skills and executive functions critical for spontaneous speech. The design is based on theoretical models that broadly agree on three stages of spoken language (conceptualization, linguistic formulation, articulation). The BELS comprises 11 subtests that assess articulation, core nominal language skills (repetition, naming and comprehension) and propositional language (connected speech and phonemic/semantic word fluency), and also incidental verbal memory. Uniquely, the BELS incorporates a sentence completion task that measures executive functions (verbal initiation, inhibition, selection and strategic processes). One-hundred and fifty-eight healthy controls and 195 acute stroke patients were recruited for the BELS development and validation studies. Construct validity was determined using confirmatory factor analysis and discriminative validity was evaluated with logistic regression. This informed the final version of the BELS, which was assessed via comparison to standard neuropsychological tests to ascertain convergent and divergent validity. The three-factor structure of the BELS was confirmed; that is, the articulation, nominal language and propositional language components comprised of uniquely different constructs. The BELS also demonstrated practical utility as a sensitive measure of aphasia as it was able to discriminate between the performance of healthy controls and stroke patients on almost all subtests. Thus, 30-50% of stroke patients were impaired on propositional language or executive function subtests. Surprisingly, the BELS incidental memory subtest revealed impairment in ~40% of stroke patients. Based on these initial findings, two of the 11 subtests were adjusted and the final version of the BELS was validated against select neuropsychological tests. The BELS is a brief, sensitive and novel tool that uniquely assesses the executive components critical for the spontaneous expression of language. In addition to assessing propositional language, the BELS is a valid and clinically useful tool for detecting articulation and nominal language deficits, along with verbal memory.

Topic Areas: Control, Selection, and Executive Processes; Disorders: Acquired

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White matter tracts underlying verbal fluency after stroke

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Verbal fluency is known to be associated with stroke risk (Brady et al., 2001) and declines after stroke (M. Babulal, 2017). Previous studies using lesion-symptom mapping have identified a number of gray matter regions associated with verbal fluency, highlighting the importance of frontal and temporal areas (Baldo et al., 2006) and dissociating semantic and phonemic fluency (Biesbroek et al., 2016). Yet a very recent study (Thye et al., 2021) has implicated damage to white matter tracts as the primary correlate for both deficits (particularly semantic fluency), rather than frontal or temporal cortical regions. It further underscored a substantial overlap between both types of fluency, suggesting that semantic fluency and letter fluency largely rely on the same neural system. This study, however, did not control for the general stroke severity, although previous evidence suggests that phonemic fluency relies more on executive processes (Faroqi-Shah and Milman, 2018). Furthermore, while lesion-symptom mapping studies in stroke offer valuable insights, their resolution - mostly dissociating frontal and temporal lesions and the use of cohorts with homogeneous lesions make them potentially less sensitive. We here focused on white matter correlates of semantic (COWAT Animals) and phonemic fluency (COWAT FAS) after stoke, with the goal of identifying white matter tracts associated with semantic and phonemic fluency, taking into account stroke severity, age, sex and level of education, as the latter 3 are known to influence performance (Loonstra et al., 2001). White matter fibre density measure was extracted from 72 tracts, using MRTRIX and TRACTSEG software in 72 participants assessed 3 months post-stroke. The results of regressions conducted separately for COWAT FAS and COWAT Animals for each tract showed that phonemic fluency was associated with the left superior longitudinal fascicle III fiber density (p=0.018), with the left arcuate fascicle and superior longitudinal fascicle II trending (p=0.059 and p=0.054). Importantly, 59 of the 72 tracts showed an association with stroke severity. No results of the COWAT FAS task survived FDR correction for multiple comparisons. For the COWAT Animals, fiber density in 17 tracts was associated with semantic fluency, of which 7 survived the FDR correction, including the arcuate fascicle, inferior cerebellar peduncle, inferior occipito-frontal fascicle, inferior longitudinal fascicle, optic radiation, superior longitudinal fascicle III, striato-occipital and thalamo-occipital tracts. All of the identified tracts were in the left hemisphere. There was an FDR significant effect of education on all tracts, and several tracts showing an association with NIHSS and sex, that did not survive correction. We conclude that verbal fluency after stroke is associated with a set of left-lateralised white matter tracts that show some overlap between semantic and phonemic fluency, namely in the arcuate fascicle and the superior longitudinal fascicle III. However, our findings emphasise that COWAT FAS is primarily associated with stroke severity rather than specific white matter tract microstructure. In contrast, while COWAT Animals task is significantly dependent on the level of education, a number of fronto-temporal tracts are specifically related to performance on the task, highlighting the important role of white matter connections for semantic fluency.

Topic Areas: Disorders: Acquired; Language Production

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Chronic aphasias after left-hemisphere resective surgery

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Surgical resection of primary left-hemisphere brain tumours is associated with an increased risk of aphasia. The overwhelming majority of post-surgical investigations have documented language performance in the acute phase (i.e., within 1 month). However, relatively little is known about post-surgical aphasia in the chronic phase (> 6 months). With modern treatment approaches combining surgery and adjuvant therapies for brain tumours, survival rates have increased. Hence, it is imperative to document the incidence of chronic post-surgical aphasia and characterise the neuroanatomical mechanism(s) responsible for poor outcomes. Using voxel-based lesion symptom mapping, we investigated whether chronic post-surgical language impairments are related to the location of surgical resection, residual tumour characteristics (e.g., progressive infiltration, oedema) or both. Forty patients who underwent surgical resection of a primary left-hemisphere brain tumour participated in the present study. Language performance was assessed with the Comprehensive Aphasia Test (CAT) between 6 and 24 months post-surgery. Thirty-one patients (77%) scored below the cut-off for aphasia on one or more subtests, with most showing deficits on verb naming, picture description, spoken and written comprehension subtests. After controlling for age, sex, education, tumour grade, chronicity and lesion volume, verb naming and spoken comprehension deficits were significantly associated with lesions comprising both the resection site and residual tumour characteristics. These lesions were predominantly in white matter tracts underlying the anterior temporal and temporoparietal regions, respectively. Spoken comprehension deficits were also significantly associated with residual tumour characteristics in the temporoparietal white matter outside of the resected areas. Lesion symptom mapping based exclusively on the resected tissue did not reveal significant associations with any post-surgical language deficits. These results indicate chronic post-surgical aphasias are common, occurring in the majority of patients in the present cohort. In addition, the nature of the aphasia reflects a combination of resection and progressive tumour infiltration of language-related white matter tracts, implicating disconnection as the critical mechanism. This information may prove useful for predicting language outcomes and planning appropriate language therapies following surgery.

Topic Areas: Disorders: Acquired; Language Therapy

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How much is enough: Atypical gamma responses in children with phonological disorders

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Introduction It is unknown what underlying mechanisms might account for the problems children with phonological disorders (PD) encounter during speech production. One possible explanation is poorly specified phonological representations. We previously examined phonological specification of place of articulation features in /bɑ/ ([labial]) and /dɑ/ ([coronal]) in typically developing (TD) versus PD children using an event-related potential (ERP) paradigm (Cummings et al., 2020). PD children exhibited less mature ERP responses relative to their TD counterparts. The present study examined neural oscillation patterns to specified and underspecified phonemes using the same EEG data of Cummings et al. 2020. The goal was to examine developmental differences in theta and/or low gamma event-related spectral perturbation responses in TD and PD children. As ERPs elicited by /bɑ/ and /dɑ/ differed between groups, it was predicted that the neural oscillation patterns underlying those responses would also be distinct. Methods Participants. Twenty-four native English-speaking children participated: 12 typically developing (TD) children (9 male, 4.58-6.92 years) and 12 children with phonological disorders (PD) (6 male, 4.00-6.92 years). Stimuli and Procedure. Two oddball stimulus sets, each containing four consonant-vowel (CV) syllables - one standard (/bɑ/ or /dɑ/) and three deviants (/bɑ/ or /dɑ/, /pɑ/, /gɑ/) - were presented in five blocks. Sixty-six channels of continuous EEG were recorded at 256 Hz. EEG Analyses. Event-related spectral perturbation (ERSP) analyses examined theta (4-7 Hz) and low gamma (25-35 Hz) band activity elicited by /bɑ/ and /dɑ/ standard and deviant syllable stimuli. ERSPs were computed from time-series data from 16 electrodes. Theta was measured in one window from 100-300 ms, while low gamma was measured in five 50 ms windows (50-300 ms). Phoneme-related differences were examined in Group (TD, PD) x Phoneme (/bɑ/, /dɑ/) repeated measures ANOVAs. Results ERSP Low Gamma Band Power. Between groups, TD children demonstrated greater low gamma activation in response to /bɑ/ standards as compared to PD children ($F(1,22) = 4.330$, $p < .05$, 2 = .164). PD children demonstrated greater low gamma activation to /dɑ/ standards than did TD children ($F(1,22) = 2.970$, $p = .099$, 2 = .119). Within the PD children, greater low gamma activation to /dɑ/ standards than /bɑ/ standards ($F(1,11) = 4.834$, $p = .050$, 2 = .305) was observed. Discussion The cortical systems mediating phonological processing in PD children exhibited a different pattern of engagement from that observed in TD counterparts. PD children demonstrated excessive synchronization in response to /dɑ/, suggesting their phonological representations were less detailed than those of TD children (Lehongre et al., 2011). Conversely, PD children demonstrated arguably excessive desynchronization in response to /bɑ/, suggesting they were processing too much information and not attending to the phoneme's distinctive features (Hanslmayr et al., 2012). This atypical pattern of cortical response to acoustic-phonological information in PD children might underlie their inability to accurately produce phonemes (Goswami, 2011). That is, these processing patterns might result in PD children storing imprecise, excessive, and/or inaccurate feature details in their phonological representations, which when accessed during speech production, would result in incorrect productions.

Topic Areas: Disorders: Developmental; Phonology and Phonological Working Memory

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Distinct relationships between neural correlates of print-sound integration and reading abilities in Chinese children with and without dyslexia

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Effortless print-sound integration is a hallmark of fluent reading and is crucial for typical reading acquisition. The underlying brain network consists of the left superior temporal cortex (STC) as the central node and other cortical areas such as the left occipito-temporal cortex (OTC) and inferior frontal gyrus (IFG) playing specific roles. Adopting the audiovisual paradigm in functional magnetic resonance imaging (fMRI) studies and comparing the congruency effect (i.e., different brain responses to congruent versus incongruent audiovisual conditions; commonly considered an indicator of multisensory integration), altered activations in both children and adults with developmental dyslexia have been reported. However, the current pieces of evidence are almost restricted to alphabetic languages. Whether such processes are also impaired in dyslexia in non-alphabetic languages (e.g., Chinese) with different linguistic characteristics remains open. Against this background, we adopted a similar fMRI audiovisual paradigm with simple high-frequency pictographic characters and pinyin (an alphabetic system helping individuals learn new character's pronunciation) as materials to examine the possible dysfunctions in Chinese school-aged children with dyslexia. Of note, while the two types of scripts are both fundamental for children's reading acquisition in Mainland China, they have quite different linguistic properties, e.g., deep versus shallow transparencies. Four experimental conditions (auditory-only, visual-only, audiovisual congruent, audiovisual incongruent) were created with each type of script. During the fMRI scan, a simple target detection task was used to help participants hold their attention. We were particularly interested in the group differences in the congruency effect (i.e., audiovisual congruent against incongruent condition) and congruency-reading correlations in the data analysis. Unexpectedly, we found no region displaying significant group differences on the congruency effect survived the whole-brain multiple corrections in either experiment. However, differences were observed in the congruency-reading associations between the dyslexic and typical controls. Specifically, in the character experiment, the congruency effect in the left IFG was correlated with morphological awareness in the control group but with rapid naming in the dyslexic group. This pattern suggests that the affected children might have not yet developed an automatic grapho-semantic mapping as their typically developing peers do, but instead more access to the articulatory information during implicit character processing. In the pinyin experiment, the congruency effects in the bilateral STC and left OTC were positively associated with oral word reading fluency in the control group, whereas children with dyslexia showed negative associations. This pattern indicates dysfunctional recruitment of the grapho-phonological circuitry in dyslexia during pinyin processing, which may have been impeding their character learning. To summarize, this fMRI study investigated the possible impaired neurofunctional basis of print-sound integration in Chinese children with dyslexia. The findings reveal that although dyslexic children recruit similar neural networks for print-sound processing, they may use these neural resources differently compared with their typical peers. Given that developing fluent reading relies on well-established grapho-phonological and grapho-semantic mappings, this study also suggests Chinese children with dyslexia may have impaired neural circuitries underlying both processes.

Topic Areas: Disorders: Developmental; Perception: Speech Perception and Audiovisual Integration

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Categorical Perception of Mandarin tones in Children with Developmental Dyslexia

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Introduction: Categorical perception is a significant characteristic of speech perception, indicating that people can perceive the continuously changing speech signals as discrete speech categories and classify the countless speech signals into limited speech categories. Studies with segmental information have found that individuals with dyslexia are hyposensitive to between-categorical stimuli and oversensitive to within-categorical stimuli compared with typical readers. Combining the between-categorical and within-categorical perception deficits, researchers proposed that dyslexics formed the abnormal perception signals instead of establishing the effective speech perception signals. Chinese is a tonal language, and tone is a kind of suprasegmental information. The tone has not only the characteristics of categorical perception, but also the unique neural mechanism. Although previous studies have examined tone perception in Chinese children with developmental dyslexia (DD), these studies mainly focused on the between-categorical perception of tone in individuals with dyslexia. According to the studies with segmental information, nonetheless, the perception deficit in individuals with dyslexia is not only related to the between-categorical attribute, but also the within-categorical attribute. By combining the between- and within-categorical performance, we can systematically reveal the categorical perception of tone in individuals with dyslexia. Methods: We adopted the level tone (/yi1/) and rising tone (/yi2/), and created tonal continua as stimuli. Two studies were designed to systematically investigated the categorical perception of Mandarin tones from the behavioral and neural levels in Chinese children with DD. Children with DD and the corresponding chronological-age control group were recruited as participants. All participants are primary school students at 5th or 6th grade in Beijing. Adopting identification and discrimination tasks simultaneously, study 1 examined the categorical perception of Mandarin tones in Chinese children with DD at the behavioral level. Study 2 examined the categorical perception of Mandarin tones in children with DD at the neural level using the passive oddball paradigm, with mismatch negativity (MMN) and late discrimination negativity (LDN) as the neural markers. Results: We have two critical findings: (1) Dyslexic children were hyposensitive to the between-categorical stimuli. Dyslexic children exhibited a smaller absolute value of identification slope and a lower accuracy in discriminating between-categorical stimuli at the behavioral level. At the neural level, compared with chronological-age children, the LDN amplitude was smaller for dyslexic children on the left, middle, and right sides of the brain; (2) Dyslexic children were oversensitive to the within-categorial stimuli. When dyslexic children perceived the within-categorical stimuli, they exhibited larger MMN than chronological-age children on the right side of the brain; (3) The between-categorical perception was positively correlated with reading performance or reading-related skills in two groups. Conclusion: The present study systematically examined the categorical perception of Mandarin tones in children with DD from behavioural and neural levels for the first time. The findings showed both the deficit of hyposensitive perception in between-categorical stimuli and the deficit of oversensitive perception in within-categorical stimuli for Chinese children with DD. This study deepens the understanding of the nature of Chinese dyslexia and inspires future intervention and remediation in Chinese children with DD.

Topic Areas: Disorders: Developmental; Reading

Slide Slam D15 Play Video

Fast, neural tuning for print in Chinese: ERP data from skilled adults and children with and without dyslexia

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Studies in alphabetic writing systems have shown that fast neural tuning for print occurs in the N1 component of the ERP with a larger negativity for familiar visual words than unfamiliar control stimuli. This N1 print tuning effect developed with learning to read and was reduced in children with dyslexia. Recent studies in Chinese with more closely matched visual control stimuli have suggested that print tuning is most prominent in the N1 onset, potentially reflecting an earlier onset of specialized print processing during the time of the P1-N1 transition. Here we aimed to replicate this effect in skilled adult readers and to test whether the size or onset of print tuning would be impaired in Chinese dyslexia. We tested children with (N=53) and without (N=47) dyslexia, as well as skilled adult readers (N=32) in an EEG one-back detection experiment with familiar Chinese and unfamiliar Korean characters. The analysis of the adults' data replicated previous findings with a more negative N1 for Chinese than Korean in the N1 onset, but a reversed effect in the N1 offset. The analysis of the children's data revealed that the N1 (onset and offset) was larger for Chinese than Korean in both groups of children, but not significantly different between the groups. However, the P1 was less positive for Chinese than Korean in the typical readers, and this difference was reduced in children with dyslexia. This interaction effect was especially pronounced in the P1 offset. The results suggest that in Chinese (and with closely matched control stimuli), print tuning and its relation to reading skills in dyslexia are reflected by differences in the P1-N1 transition. This is in agreement with the idea that reading expertise facilitates print processing by speeding up early visual processes, and that such facilitation is absent in dyslexia.

Topic Areas: Disorders: Developmental; Reading

Slide Slam D16 Play Video View PDF

Neural responses to explicit processing and implicit representation of lexical tones in Mandarin speakers with Amusia

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Introduction The present study investigates whether pitch deficits in congenital amusia extends to lexically contrastively pitch patterns and whether such deficits affect both explicit processing and implicit representation of lexical tones. Mandarin-speaking adults with and without amusia engaged in two sets of experiments that target neural processing and representation of Mandarin tones and musical pitch. Methods Thirty-six native Mandarin Chinese speakers participated in the study with half identified as amusics by the Montreal Battery of Evaluation of Amusia (MBEA). The subjects participated in two fMRI sessions (processing and representation). The processing session consisted of explicit music and lexical tone discrimination tasks in separate blocks. The representation session comprised a loudness judgement task for a sequence of lexical tone pairs while in half of the blocks the lexical tone repeated across the syllables. We compared subjects with and without amusia for both the tone and music processing tasks and between repeat and non-repeat trials in the representation task. GLM analysis was conducted using SPM12. Regions showing significant task and group differences were used as ROIs in the subsequent correlational and SVM-classification analyses. Results Behaviorally, subjects with amusia were less accurate than those without amusia (control subjects) in both music and tone discrimination tasks. The brain data suggested that, for the processing task, the control group produced stronger activation in the right superior temporal gyrus (STG) in two non-overlapping areas, separately, for the tone and music stimuli, in the ventral and dorsal parts of the gyrus correspondingly. The behavioral accuracy in the music task across all subjects correlated with the activity in the right dorsal STG area that showed the group effect for music. fMRI data classified the participants into amusic and control groups as well as behavioral data in the music task and better than behavioral data in the tone processing task. The representation task revealed one left dorsal STG area with a marginally significant group effect, and the group classification based on activation in this area was at chance level. Discussion We found significant group effects in right STG in the tone processing task, but not in the implicit representation task. Consistent with previous fMRI studies, speech was associated with more ventral part of STG than music (Norman-Haignere et al, 2015; Rogalsky et al., 2011). The performance in music but not tone processing task was correlated with fMRI activity in brain areas showing group effects. Traditional GLM analysis was confirmed by SVM classification analysis. Altogether, our data suggest that while different cortical systems support language and music pitch processing in individuals with and without amusia, such distinction is not shown in the implicit representation task. Lexically relevant pitch deficits in amusia may be restricted to processing only.

Topic Areas: Perception: Auditory; Disorders: Developmental

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Cross-modal effects of pseudo-sign articulation (overt and covert) on the extrastriate cortex: an adaptation fMRI study

Stephen McCullough[1], Karen Emmorey[1]; [1]SDSU

Tian and Poeppel (2013) found that both overt and covert speech enhanced activation in auditory cortex: overt speaking and imagined speaking both increased the neural response to the same (subsequently presented) auditory syllable. In contrast, auditory imagery (imagine hearing the syllable) and actually hearing the syllable both suppressed the neural response to the heard syllable probe (a repetition priming effect). We investigated whether similar effects occur in visual-manual language: American Sign Language (ASL). We created grayscale videos of a right hand producing eight different pseudosign syllables (probe stimuli) and 24 scrambled videos (adaptor stimuli) with a transparent square cue in the middle (gray for overt and black for covert production). Each square also had one of eight different false font pictographs, corresponding to each pseudo-sign. Prior to scanning, deaf signers learned the association between each pseudosign and pictograph. Participants also learned to articulate the pseudosigns overtly or covertly, depending on the color of square cue in the scrambled videos. The fMRI study consisted of four event-related fMRI adaptation scans and two blocked-design functional localizers. The functional localizer scans always followed the adaptation scans. The first localizer (LOC1) identified the cortical regions involved in viewing hand and foot motor actions. The stimuli for LOC1 consisted of a randomized order of 20s blocks showing videos of pseudosigns, foot motor actions, and scrambled videos without the square cue or pictographs. We instructed participants to pay attention to the LOC1 stimuli silently during the run. The second localizer (LOC2) identified the regions involved in producing hand motor actions. The LOC2 stimuli consisted of a randomized order of 20s hand or foot blocks showing scrambled videos with pictograph cues. Participants produced either hand or foot motor actions corresponding to the pictographs (learned prior to scanning). For the event-related fMRI adaptation, participants viewed a total of 256 trials of video pairs (2s each) separated by 1s. The first video of each pair (adaptor) was always selected randomly from four categories: overt articulation (AV), covert articulation (CV), visual imagery (VI), visual presentation (V). The second probe video always showed a pseudo-sign that was either the same pseudosign or a different pseudosign from the adaptor stimulus. We use the conjunctions of neural activation clusters identified in both LOC1 and LOC2 as the regions of interest (ROIs) for our analysis of BOLD responses acquired from the adaptation scans. Preliminary results for cross-modal adaptation from sign production to sign perception indicate repetition suppression (reduced BOLD response) occurred in the extrastriate cortex when a covertly articulated pseudosign (adaptor stimulus) was the same as a visually presented pseudosign (probe stimulus) vs. when a different pseudosign was articulated as the adaptor. However, no repetition suppression was observed when the adapting stimulus was an overtly articulated pseudosign and the visual probe was the same pseudosign. This preliminary result (5 deaf signers) suggests that imagined (covert) signing accesses visual representations of pseudosigns, while overt articulation does not, perhaps due to the nature of visual feedback in sign language.

Topic Areas: Signed Language and Gesture; Language Production

Slide Slam E2 Play Video

Tracking the time-course of sign recognition using ERP repetition priming

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An important distinction between signs and spoken words is that the linguistic articulators for speech are largely hidden from view, but are directly observable for sign language. This difference has direct consequences for how individual words and signs are perceived when presented in isolation. For example, the movement of the tongue in the word “gold” is not visible and not perceptible auditorily before voicing begins. Thus, the onset of an audio clip of the word “gold” and the onset of the stimulus word are identical. In contrast, the onset of a video clip of the sign GOLD from American Sign Language (ASL) typically begins with the sign model’s hands at rest and then her hand transitions to the target location of the sign at the cheek. Thus, the onset of the stimulus video and the onset of the sign are not identical. Further, this transitional movement may contain useful information about sign identity (e.g., early cues to handedness and hand configuration). The visibility and dynamic nature of the sign articulators creates a linguistic signal that is distinct from both auditorily and visually presented words. In this study, we used repetition priming and event-related potentials (ERPs) to investigate the time course of sign recognition in deaf ASL signers. Signers performed a go/no-go semantic categorization task to rare probe signs referring to people; critical target items were repeated and unrelated signs. In Experiment 1, ERPs were time-locked either to the onset of the video or to sign onset within the video; in Experiment 2, the same full videos were clipped so that video and sign onset were aligned (removing transitional movements), and ERPs were time-locked to video/sign onset. All analyses revealed an N400 repetition priming effect (less negativity for repeated than unrelated signs), but differed in the timing and/or duration of the N400 effect. Results from Experiment 1 revealed that repetition priming effects began before sign onset within a video, suggesting that signers are sensitive to linguistic information within the transitional movement to sign onset. The timing and duration of the N400 for clipped videos was more parallel to that observed previously for auditorily-presented words and was 200 ms shorter than either time-locking analysis from Experiment 1. We conclude that time-locking to full video onset is optimal when early ERP components or sensitivity to transitional movements are of interest and that time-locking to the onset of clipped videos is optimal for priming studies with fluent signers.

Topic Areas: Signed Language and Gesture; Methods

Slide Slam E3 Play Video

Electrophysiological signatures of spoken word production

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Spoken word production models assume multiple stages of processing are needed to retrieve and produce a word (i.e., conceptual, lexical, and phonological word form retrieval, and articulation). One naming paradigm that has been used to test these models is Picture-Word Interference (PWI). In PWI, participants are asked to name a picture while ignoring written distractor words Two effects observed in this paradigm are semantic interference and phonological facilitation. The former refers to slower target naming latencies when distractors are semantically related to the target compared to unrelated (e.g., wolf-PIG vs. violin-PIG), while the latter refers to facilitated naming with phonologically related distractors (e.g., pin-PIG). These two effects have been well investigated with behavioural studies, with many studies demonstrating them within a limited range of Stimuli Onset Asynchronies (SOAs; between -150 and 150 ms). Behavioural data can provide insight on how different stages of the production process interact with each other, the use of electrophysiology can shed light, thanks to the high temporal resolution, on the timing of different stages and help to resolve the debate about different model architectures (e.g., serial, cascade, interactive). Additionally, it can contribute in updating current neurophysiological models of speech production. However, the reported electrophysiological findings for these PWI effects are inconsistent across studies. The result most commonly reported for semantic interference is an N400-like ERP modulation while no clear result has been reported for phonological facilitation (de Zubicaray & Piai, 2019). While ERPs can provide information about the timing of the process, analysis of oscillatory activity can provide additional information about underlying, non-phase locked, neural processes. The aim of this experiment is firstly to replicate the ERP effects previously reported for semantic interference (e.g. Dell'Acqua et al., 2010; Piai, Roelofs, Jensen, Schoffelen, & Bonnefond, 2014). Secondly, we aim to identify the ERP effects associated with phonological facilitation, and thirdly we aim to analyse the neuronal oscillations associated with lexical and phonological word form retrieval processes, hypothesized to be represented in the Beta (12-30 Hz) and Theta (4-7 Hz) frequency ranges, distinguishing them from the oscillations underpinning other processes (e.g. articulation). EEG data (64 channels) from 24 subjects has now been collected using a PWI paradigm in two separate experiments (semantic interference and phonological facilitation). Data analysis is ongoing, and results will be presented at SNL.

Topic Areas: Language Production; Meaning: Lexical Semantics

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Behavioural and electrophysiological markers of integration in novel word learning

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According to the Complementary Learning Systems model, learning involves the formation of new episodic memory representations and their later integration into semantic memory (McClelland et al., 1995; McClelland, 2013). Applied to word learning, this model predicts that only integrated newly learned words can compete with familiar words during lexical selection in tasks that require activation of multiple components of the lexical system (Davis & Gaskell, 2009; McMurray et al., 2016). Semantic priming is one such task, in which participants are presented with pairs of words – primes and targets – and asked to make a judgement to the target (e.g., McNamara, 2005). When the prime is semantically related as opposed to unrelated to the target (e.g., bed-sofa vs. hat-sofa), participants make judgements faster and the amplitude of the N400 ERP component is reduced, while that of the Late Positive Component (LPC) is enhanced. Studies tracking semantic integration of new vocabulary have frequently (although not always) reported the behavioural priming effect, yet it is unclear whether it indexes integration as it could be subserved by either semantic or episodic memory system. This issue can be addressed by examining whether the behavioural effect co-occurs with the modulation of both ERP components or LPC only (e.g., Bakker et al., 2015; Batterink & Neville, 2011; Liu & van Hell, 2020). This is because the N400 component is believed to reflect automatic processes of lexical-semantic retrieval (e.g., Kutas & Federmeier, 2011), while the LPC has been linked to episodic memory retrieval (e.g., Rugg & Curran, 2007). This study used a version of the semantic priming paradigm that taps into automatic semantic processing to investigate this issue. 72 monolingual native speakers of Australian English learned novel names for two sets of novel concepts (20 words per set), one set on each of two consecutive days. EEG was recorded on Day 2 when learning was followed by a primed continuous lexical decision task, with newly trained words as targets, and familiar (semantically related or unrelated) words as primes. Recall of the novel words was also tested. For the EEG data, two types of analyses have been pre-registered: the amplitude averaging approach and the mass univariate analysis (e.g., Groppe, Urbach, & Kutas, 2011a, 2011b). The former approach is used as it is most common in the literature, while the latter will explore other time windows and ROIs for the contrasts of interest. Averaged amplitude and behavioural data will be analysed with linear mixed effects models. Data collection for this study was completed in the second half of May 2021. Data analysis is expected to be completed in July 2021. This study is the first to examine electrophysiology of behavioural effects commonly interpreted as markers of integration with a paradigm that taps into automatic semantic processing. We hypothesise that response speed as well as the N400 and LPC amplitude in response to the newly trained words will be modulated by prime-target relationship and time after exposure (24h vs. 0h), indexing differences in integration.

Topic Areas: Multilingualism; Language Production

Slide Slam E5 Play Video

The effect of immersion on emotional word processing in a second language: an fMRI study

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Studies on the embodiment of emotional words in a second language (L2) have received increasing attention recently. In behavioral L2 studies, Harris (2006) and Dewaele (2010) suggested that learning context is a critical factor influencing the processing of emotional words, and L2 can be made emotional if it has been used frequently in immersive contexts (e.g., study abroad settings). However, limited research has explored the effect of immersion on the neural representation of L2 emotional words. Hence, we conducted an fMRI experiment to explore the neural correlates of the immersion effect on emotional word processing with L2 learners who had varied immersion intensities in study abroad settings. The participants were 41 healthy, right-handed Chinese native speakers living in Japan (mean age 24.95, 24 females). All Chinese speakers learned Japanese as their L2. Their L2 proficiency level was measured by the Japanese C-test, which requires the participants to fill in the missing words that have been deleted within a short text. In order to assess the intensity of immersion, we adopted the Study Abroad Social Interaction Questionnaire (SASIQ, Dewey, 2012), where participants estimated how many hours per week they communicated with acquaintances (limited to Japanese speakers) who scored five and above in an intimacy rating task (from “1” an acquaintance to “8” a very close friend). The total hours of communication with Japanese speakers were adopted as an indicator of immersion intensity. The participants performed an auditory lexical decision task with four types of auditory words [40 positive words, 40 negative words, 40 neutral words, and 80 nonwords] inside the fMRI scanner. Statistical analyses were performed with SPM12, using a random-effects model. To identify the immersion effect on L2 word processing, we performed whole-brain multiple regression analyses with the immersion intensity scores of each participant as an independent variable and brain activity as a dependent variable, using the contrasts of each type of words vs. Nonwords. To control the level of linguistic proficiency, we entered the C-test score as a covariate. A significant positive correlation was observed in the contrast of [Positive words > Nonwords] between the left ventral striatum activity and immersion intensity scores ($p < 0.05$ FWE-corrected voxel-wise). However, no significant correlation was found in the contrasts of [Negative words > Nonwords] and [Neutral words > Nonwords]. These results may reflect that learners had more chances to use positive words in real-life contexts, known as a positive advantage (Sheikh & Titone, 2016). As immersion intensity increases, L2 learners may efficiently retrieve the conceptual knowledge of positive emotion words and readily integrate their experiences and semantic knowledge to process L2 emotional words.

Topic Areas: Multilingualism; Meaning: Lexical Semantics

Slide Slam E6 Play Video View PDF

How bilinguals dynamically comprehend words in the text: Evidence from functional connectivity and network science

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Introduction: Numerous studies have investigated neurocognitive differences between first (L1) and second (L2) languages in reading, but most of this literature has focused on single-word reading. Reading of whole sentences and paragraphs involves more component processes such as inference and integration than single-word reading. Further, naturalist reading involves backward saccades that are not possible within a RSVP paradigm in which single words are presented one by one. These differences point to potential different neural mechanisms involved in text vs. single-word reading. In this study, we use functional connectivity (FC) and network science-based graph metrics to study large-scale networks supporting L1 and L2 naturalistic reading of text. Methods: Fifty-two native English speakers (L1, 18-40 years old) and 56 Chinses-English (L2, 19-38 years old) speakers were recruited to read expository texts in English saliently. Fixation-related fMRI method was employed to record eye-movements and blood-oxygen-level-dependent (BOLD) signals simultaneously. First-pass reading time measures the sum of all fixations counting from first-time eye landings on targets until leaving. Second-pass reading time measures the sum of all fixations on targets after the first-pass reading time. Both were employed as events to convolve BOLD signals for words that were re-read. FC during reading was measured with large-scale networks, and network-based statistical analysis was adopted. In addition, topologies of subnetworks were further measured with graph metrics. Results: We found significantly different patterns for first-pass and second-pass reading. (1) During the first-pass reading time, one subnetwork was identified for the contrast “L1 > L2”, mainly encompassing connections between occipital and prefrontal areas, between occipital and temporal areas, between prefrontal and parietal areas, and within the occipital cortex. Six hubs (e.g., the left precentral gyrus and the right middle frontal gyrus) were identified. Another subnetwork was detected for the contrast “L2 > L1”, mostly involving connections between prefrontal and other cortical areas, between occipital and parietal areas, and within the prefrontal cortex. Six hubs (e.g., the right dorsal-lateral superior frontal gyrus (DLSFG) and the left middle temporal gyrus) were identified; (2) During the second-pass reading time, one subnetwork was found for the contrast “L1 > L2”, mainly consisting of connections between parietal and other areas and within the occipital cortex. Seven hubs (e.g., the bilateral posterior cingulate gyrus (PCG)) were identified. Another subnetwork was reported for the contrast “L2 > L1”, primarily comprising connections between prefrontal and temporal areas, parietal and occipital areas, and within the prefrontal cortex. Six hubs (e.g., the right DLSFG and superior temporal gyrus) were identified. Conclusion: Our study suggested great engagement of a distributed network for L1 during the first-pass reading time, while L2 relied more on the prefrontal system. During the second-pass reading time, there was more engagement of the parietal system for L1, while L2 mainly utilized the prefrontal-temporal system. These data differ from previous neuroimaging studies of single-word reading, showing that distinct neural cooperative systems were dynamically recruited in L1 and L2 reading of text, systems that are necessary for additional cognitive resources employed by L2 readers in text comprehension.

Topic Areas: Multilingualism; Reading

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The Effect of L2 Proficiency in Grammatical Processing: An fMRI Study

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The extent to which grammatical representation and processing in second language (L2) rely on the same brain networks as first language (L1) is a fundamental issue. Previous neuroimaging studies showed that L1 grammatical processing recruits several key brain regions, such as the left inferior frontal gyrus (LIFG) and posterior superior temporal gyrus, which have been reported as critical areas for detecting grammatical errors. In contrast, grammatical processing by adult L2 learners is less efficient and automatic, recruiting the additional regions related to cognitive control (e.g., anterior cingulate cortex) and semantic analysis (e.g., angular gyrus) for compensating processing difficulties (e.g., Roncaglia-denissen & Kotz, 2016). While L2 proficiency presumably contributes to the development of L2 neural systems, it remains unclear whether increased L2 proficiency would result in L2 grammatical processing engaged in a native-like neural mechanism. To further clarify the role of L2 proficiency in grammatical processing, we conducted an fMRI experiment by recruiting L2 learners and L1 speakers to perform an Auditory Grammatical Judgment Task (AGJT) with L2 proficiency level as a factor of interest. Twenty-one healthy, right-handed L2 learners of Japanese with L1 Chinese background (mean age: 24.05±1.72; 15 females) and 21 native Japanese speakers (mean age: 21.57±1.62, 7 females) were asked to perform the AGJT. The AGJT contains 64 Grammatical [G] and Ungrammatical [U] sentences with syntactic structures that do not exist in L2 participants' L1 Chinese. Participants were instructed to judge the grammaticality of each sentence within 10 seconds during an fMRI scanning. L2 learners' general proficiency level was measured by using Japanese C-tests (a passage-based fill-in-the-gap test). For the brain data analysis, first, to investigate the group differences in processing grammatical error, we analyzed the brain activation in the contrast [U > G] for both L1 and L2 groups, respectively. We then compared the brain activation between L1 and L2 groups for the contrast [U > G] with two-sample T-tests implemented in SPM12 (corrected to $P < 0.05$ at cluster level). Second, to investigate the effect of L2 proficiency, correlation analysis using the proficiency scores of each L2 learner was performed at the whole-brain level for the [U > G] contrast. The results for group differences showed that the L1 speakers engaged higher activation of the LIFG than L2 learners in response to grammatical errors [U > G]. In contrast, the L2 learners recruited greater activation in the anterior cingulate cortex and the left angular gyrus than the L1 speakers. Notably, a significant positive correlation between activation in L2 [U > G] and proficiency level was found in the LIFG. Taken together, these findings suggest that L2 grammatical processing heavily demands cognitive control and sentence meaning analysis. However, with increased L2 proficiency, L2 learners can efficiently process grammatical information engaged in the same brain mechanism as native speakers.

Topic Areas: Perception: Auditory; Syntax

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Selective disruption of sentence comprehension by transcranial alternating current stimulation over the left inferior frontal cortex

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Previous neuroimaging studies have demonstrated that the cortical activity of different frequency bands tracked the construction of hierarchical structures, such as syllables, phrases, and sentences. Using transcranial alternating stimulation (tACS), which can modulate the specific frequency band of the cortical activity non-invasively, we examined whether the modulation of the cortical activity that corresponded to sentence structure construction changed sentence comprehension. We recruited 15 right-handed native speakers of Japanese (8 males, 21.9±0.8 years), who had no history of neurological or psychiatric diseases. The same participants were tested for both tACS and sham sessions. We used 96 Japanese sentences and 96 word strings (total 192 stimuli). Each sentence consisted of three noun phrases and one verb (e.g., Shimbun-no kisha-ga machigai-o naoshita, A newspaper reporter corrected a mistake), immediately followed by a question consisted of a subject and a verb (kisha-ga naoshita?, Did the reporter correct it?). Each word list consisted of four nouns or verbs (aratta tataita naoshita okutta, washed hit corrected sent). In the present experiment, we used a sentence comprehension task and a short-term memory task. In the sentence comprehension task, the participants judged whether the meaning of the sentence matched with the question, while in the short-term memory task, they judged the order of words. We used a double-blinded sham-controlled design. Stimulation was delivered using DC-Stimulator Plus (NeuroConn GmbH, Germany). The two electrodes were placed over F7 and Fp2 according to the International 10-20 EEG system, which were right above the left IFG and the right forehead, respectively. For the tACS, stimulation was given for 20 minutes (±2 mA, 0.5 Hz, 5 cm * 7 cm saline-soaked sponge electrodes, >10 kΩ). Sham stimulation, which controlled for the placebo effect, ramped up to ±2 mA over 10 s, remained at that level for 30 s, and ramped back down over 10 s. The participants felt the initial ramp-up event in the sham session, which is the most noticeable, without receiving an effective stimulation. Before and after the tACS and sham sessions, the participants performed the sentence comprehension and short-term memory tasks. The participants showed high accuracies (>90%) and short reaction times to comprehension questions (RTs, <1000ms). To consider the random variabilities of participants and stimuli, we analyzed the RTs by using a linear mixed-effect model (lme4 and lmerTest packages on R). We found that the model with the effects of Stimulation (baseline vs. tACS vs. Sham) and Task (sentence vs. memory) was significantly better than the simpler model without the effect of Stimulation (2(4)=18, p=0.001), suggesting the effect of tACS was significant. Moreover, the sham stimulation over the left IFG significantly decreased the RTs of the sentence comprehension task (t(2510)=−3.7, p=0.0002), indicating the learning effect. In contrast, the tACS over the left IFG did not show such effect (t(2505)=−1.7, p=0.08). In the present study, we demonstrated that the tACS over the left IFG interrupted the sentence comprehension task but not the short-term memory task, suggesting the causal relationship between the left IFG activation and sentence structure constructions.

Topic Areas: Syntax; Meaning: Combinatorial Semantics

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Statistical learning contributes to sentence comprehension in a foreign language learned through a non-immersive environment

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Recent literature has indicated that statistical learning (SL) contributes to language processing and acquisition regardless the population is infants or adults. Our previous research also demonstrated the association between SL and Chinese character recognition in native speakers and foreign learners through behavioral and neuroimaging findings. However, further evidence is needed to determine the relationship between SL and other aspects of language processing and acquisition. To address this issue, we examined whether SL was correlated with the semantic and syntactic processing of sentences in a foreign language. Specifically, 49 Taiwanese college students with relatively high proficiency in English were presented with English sentences when their neurophysiological responses to the sentences were simultaneously recorded. After excluding participants with low accuracy in the acceptability judgment task or with excessive artifacts in the neurophysiological signals, 34 participants' data were analyzed further. Event-related potentials (ERPs) elicited by semantically and syntactically anomalous words, compared to those elicited by control words, in the sentences revealed robust N400 and P600 effects, respectively. These results were consistent with the findings from native speakers, despite the fact that our participants learned English in a non-immersive environment with only several hours of formal classes a week. Critically, the magnitude of the N400 effect was correlated with the ability of SL (measured by a conventional triplet segmentation task) significantly after individual differences in English proficiency, IQ, and working memory were controlled by taking the scores in the TOEIC, Block Design, and Corsi Block tasks into account. On the other hand, the P600 effect was not correlated with the ability of SL. The present results provided supporting evidence for the relationship between the domain-general pattern learning mechanism underlying SL and the domain-specific semantic processing mechanism underlying foreign language comprehension. More research would help clarify whether SL contributes to the acquisition of semantic and syntactic regularities in a foreign language.

Topic Areas: Meaning: Lexical Semantics; Syntax

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Graph and not vector-embedding models: Computational mechanisms for neural representation of words

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A critical way for humans to acquire knowledge is through language, yet the underlying computation mechanisms through which language contributes to our word meanings are poorly understood. We compared three major types of computation mechanisms that derive word-relational structure from a large language corpus (simple co-occurrence, graph-space relation and vector-space relation) in terms of the association of words with brain activity patterns, measured by two functional magnetic resonance imaging (fMRI) experiments. Word relations derived from a graph-space representation, and not the other two types, had unique explanatory power for the neural activity patterns in brain regions that have been shown to be particularly sensitive to language processes, including the anterior temporal lobe (capturing graph-common-neighbor), inferior frontal gyrus, and posterior middle/inferior temporal gyrus (capturing graph-shortest-path). These results were robust across different language co-occurrence measuring window sizes and graph sizes and were relatively specific to language inputs, as they were not associated with stimuli structures that had the same computations derived from visual co-occurrence statistics. These findings highlight the role of cumulative language inputs in shaping word meaning representations in this set of brain regions and provide a mathematical model to explain how they capture different types of language-derived information.

Topic Areas: Meaning: Lexical Semantics; Computational Approaches

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How Neural Activities during Encoding Novel Words and Resting Predict Memory Retrieval after Different Time Scales?

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To tell the fate of novel words by their learning process is crucial to reveal the mechanism for effective word learning. The widely accepted Subsequent Memory Effect indicated that the neural activity during encoding could predict the memory performance. Therefore, the present study aimed to explore the neural features of encoding for successful novel word learning. In addition, the neural pattern similarity was introduced to capture the neural correlates of the encoded information recently, whereas a debate about whether greater or smaller similarity is associated with better memory performance emerged, which need further exploration. Moreover, neural oscillations in the resting phase could predict subsequent memory. However, these subsequent memory effects on neural activity were mostly discovered within a short time lag, opening another question for the present study, that how neural activities during encoding novel words and follow-up resting predict successful retrieval after a longer time interval. Participants (N = 40, 33 females, Mage = 19.6 years) memorized 90 novel word-picture associations twice. After a 5-min quiet rest, the novel words were tested in a semantic category (living or not living) and a recognition (choosing picture from three alternatives) task. After one month, they were tested again. We coded the novel words categorized and recognized correctly as the remembered items and the rest as forgotten items for 5-min and 1-month intervals respectively. First, we captured the subsequent memory effect on LPC (800~1400ms) for both intervals as remembered novel words elicited more positive-going LPC than forgotten items (covering frontal and central regions for 5-min interval, while only frontal region for 1-month interval). These results revealed that typical SME on LPC could predict long-term memory retrieval at both short and long time lags. Second, within-item spatiotemporal pattern similarity of remembered items in 5-min interval was larger than that of forgotten items in an early time window (-70~120ms) at left frontal and central regions, while an opposite effect was found later (240~480ms) at frontal region. The pattern for 1-month interval was similar, showing a pre-stimuli effect (-440~-270ms) at right posterior region and inversed later (650~1100ms) at left frontal region. Early greater similarity associated with better memory might contribute to the specific item encoding, whereas the late smaller similarity for better memory might involve association encoding which aligned with the Encoding-variability hypothesis. Third, there was a negative correlation between the subsequent memory performance and the power of alpha oscillation in resting phase, which might reflect increased information processing. However, the activity during rest failed to predict the memory after one month. Our results manifested the classic subsequent memory effect after a long time interval for novel word learning and limited the prediction power of oscillation during rest for longer time memory. More importantly, we figured out a complex correlation between the neural activity of the encoding and the memory performance after short and long time intervals.

Topic Areas: Meaning: Lexical Semantics; Development

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A multi-perspective study of the neural representation of lexical semantics

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Introduction & Objective：We already found that semantic processing involves widely distributed brain regions(Patterson et al., 2007，Hinton, 1989; Plaut & McClelland, 2010). but how are semantic concepts organized and represented? There is still no common conclusion on this issue Some related studies that tested the neural basis of semantic categories rely on handpicked or corpus-derived semantic features of low interpretability, which may ignore important psychosemantic features and lead to biased results(Wang et al., 2018). Recently, spontaneous report-based large-scale semantic network models built through word association paradigms covering enough words (nodes) and associations (edges) have been proposed to contain real psychosemantic features(De Deyne et al., 2019; Jorge-Botana et al., 2018）. This may provide a more appropriate model for investigating the neural basis of semantic concept organization, but no semantic model of Chinese word associations of sufficient scale has been established. Methods：Therefore, we first established a large-scale Chinese word association semantic network model SWOW-ZH. Next, through the method of representational similarity analysis(Kriegeskorte et al., 2008), differences in neural representations of word concepts measured by functional magnetic resonance imaging were compared with the semantic distance of these words in SWOW-ZH and two-word embedding models: Word2Vec and ConceptNet. Stimulus words and semantic categories were determined in a data-driven approach. A semantic community detection algorithm was applied on each of the three semantic models, resulting in 72 two-character words from 9 communities shared by the models. Representational dissimilarity matrices of the stimuli were constructed at three levels of granularity: the community level (the coarsest), the cluster level, and the node level (the most fine-grained). regions of interest were independently analyzed for the representational similarities using the semantic models at the three granularity levels. Results & Discussion：We found that neural representations of the similarity patterns of word concepts were most consistent with SWOW-ZH at all three granularity levels at the whole-brain level. Specifically, at the community level, most similar regions to SWOW-ZH include a wide range of the anterior temporal lobe, the temporoparietal, and the lateral occipital areas. While at the node level, significant similarities are mostly localized in the anterior temporal lobe. These results reveal that：first, representations of word semantics in the word association network SWOW-ZH are more similar to the neural representation of semantics than the word embedding models, suggesting that it encodes a wider range of mental semantic features. Second, neural semantic representations are found hierarchically structured along the gradient from temporooccipital cortices to the anterior temporal lobe. Third, the anterior temporal lobe encodes semantic information of different granularities, supporting the Hub-and-spoke Model the proposal that the anterior temporal area is the hub of integrating semantic features from multiple sources and encoding semantic similarities(Patterson & Lambon Ralph, 2016; Patterson et al., 2007). Conclusion：Overall, the findings have advanced our understanding of the neural representations of semantic knowledge, and have highlighted that constructing semantic networks from large-scale behavioral data might make important contributions to studying semantics in various fields.

Topic Areas: Meaning: Lexical Semantics; Meaning: Combinatorial Semantics

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Older people are not better at reading between the lines: Aging effect of conversational implicature (CI) processing

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Much attention has been paid age-related decline in semantic and syntactic processes; however, it remains unclear whether there is age-related alteration in comprehension of conversational implicature (CI). In the present study, 43 healthy native Chinese speakers (21 younger adults and 22 older adults) were asked to read Direct Expressions (DIR), Indirect Expressions (INDIR), and Face-Saving Expressions (FS) dialogues during fMRI scanning, followed by T1 and DTI scanning. While worse behavioral performance was found in the older group than in the younger group, higher vocabularies have led to shorter RTs for the elderly only. The fMRI results showed age effect on CI parametric modulation in the left frontal pole, the medial prefrontal cortex, the left middle frontal gyrus, and the left middle temporal gyrus, with decline of adaptive response was found in the older group than in the younger group. Correlation analysis revealed that higher activation of the left frontal pole and right middle temporal gyrus compensated the behavior by leading to shorter RTs, while higher activation in the left caudate and left middle frontal gyrus showed lower neural efficiency by leading to longer RTs. The preserved functional adaptive response positively correlated with better gray matter volume in the left frontal pole, left middle frontal gyrus, and right inferior frontal gyrus in the elderly. We also found that functional adaptive response of the left frontal regions positively associated with the fractional anisotropy (FA) of the left corona radiata and the genu of the corpus callosum for the younger adults but disappeared in the elderly. In summary, even richer in verbal and social experience, the elderly still showed a significant decline in CI comprehension. In addition, the results showed that age-related reductions in efficiency and successful compensation could co-exist in the same older adults in a given task, but not exclusive. The present study also suggests that minor brain function adaption in the elderly is associated with age-related disrupted in brain structures.

Topic Areas: Meaning: Discourse and Pragmatics; Development

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Not all inference is the same : Dissociable forms of human inference during narrative comprehension revealed by NLP language models

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A vast experimental literature demonstrates that language comprehension relies on the ability of comprehenders to access general event knowledge that is not explicitly stated in the narrative. The current research investigates how such event knowledge may be coded in language models developed in the context of natural language processing (NLP) in machine learning. We investigate inference on events using two well documented protocols from Metusalem et al. 2012 and McKoon &Ratcliff 1986 (hereafter Metusalem and McKoon), and demonstrate dissociation in the relation between local semantics vs event-inference depending on the language model. In Metusalem, subjects are exposed to a sentence, or to the same sentence preceded by an event evoking discourse, and then tested on one of three types of words: Expected, Unexpected-Related, Unexpected-Unrelated. In the sentence context, N400s are increased for both Unexpected types with respect to Expected. In the event-evoking discourse, the N400 for the Unexpected-Related type is rescued, revealing access to event knowledge that allows inference. In McKoon, subjects are exposed to one of two sentences that either evoke a context, e.g. about writing a letter, or use many of the same words but do not evoke that context. Subjects are slower to report that the target word did not appear in the sentence, only for the context-evoking sentences, revealing access to event representations that prime the target word. We previously reproduced the Metusalem results using a discourse vector made by averaged Wikipedia2Vec embeddings (Uchida et al. 2021). In the current research, we compared inference performance (Unexpected-Related vs Unexpected-Unrelated) and simple Semantic performance (related vs. unrelated word pairs from Chwilla et al. 1995) for 22 language models based on word2vec and GloVe, and found a highly significant correlation between Semantic and Metusalem-Inference. We made the same comparison between Semantic performance and McKoon-Inference. In this case, increased performance on the Semantic task did not correspond to increased performance on the inference task. This indicates that inference as measured by Metusalem and McKoon rely on dissociable processes in the context of word2vec-based models. We further analyzed these processes by replicating the study using 23 Bert language models. Bert is designed to encode sentence context, and we thus predicted that it would demonstrate a more robust correlation between semantic and inference processing. Indeed, we observed the strong correlation between Semantic and inference processing for the Metusalem task, as before, and no relation between Semantic and Inference processing for McKoon inference. This indicates that inference as measured by Metusalem and McKoon rely on dissociable processes in the context of Bert-based models. Inference as assessed by Metusalem and McKoon rely on dissociable processes. Word2vec and Bert both allow modeling of local semantic processing. For comprehension that relies on access to knowledge of events, Bert provides a model that is more consistent with human processing as assed by Metusalem, but not by KcKoon. Future research should address the computational underpinnings of these phenomenological observations.

Topic Areas: Computational Approaches; Meaning: Lexical Semantics

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Predictability facilitates comprehension of but not adaptation to degraded speech in a graded manner

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Previous studies have shown a facilitatory effect of semantic predictability on language comprehension at moderate levels of spectral degradation (Obleser & Kotz, Cereb Cortex. 2010). It is argued that when speech is degraded, listeners have 'narrowed expectations' about the sentence endings, i.e., semantic prediction may be limited to only most highly predictable sentence completions (Strauß et al., J Cogn Neurosci. 2013). It has also been shown that listeners adapt to the speech presented at the same level of degradation when the semantic predictability of the sentences is kept constant (e.g., only low predictability sentences), showing performance improvements over the course of the study (Erb et al., J Neurosci. 2013). The main objectives of this study were (i) to examine whether listeners form narrowed expectations, or they form predictions across a wide range of probable sentence endings, and (ii) to assess the relationship between perceptual adaptation and the facilitatory effect of sentence predictability. For this, we created 360 German Subject-Verb-Object sentences that varied in semantic predictability of a sentence-final target word in a graded manner (high, medium, low) and levels of spectral degradation (1, 4, 6 and 8 channels noise-vocoding). These sentences were presented auditorily to two groups: One group (n=48) performed a listening task in an unpredictable channel context in which the degraded speech levels were randomized, while the other group (n=50) performed the task in a predictable channel context in which the degraded speech levels were blocked. The results showed that at 4-channels noise-vocoding, response accuracy was higher in high-predictability sentences than in the medium-predictability sentences (β=1.14, SE=0.37, z (1608)=3.10, p=.002), which in turn was higher than in the low-predictability sentences (β=1.01, SE=0.24, z (1608)=4.20, p<.001). This suggests that in contrast to the narrowed expectation view, comprehension of moderately degraded speech ranging from low to high including medium predictability sentence conditions are facilitated in a graded manner; listeners probabilistically preactivate upcoming words from a wide range of semantic space, not limiting only to highly probable sentence endings. Additionally, in both channel contexts, we did not observe learning effects, i.e., response accuracy did not increase over the course of experiment (β=-0.0001, SE=0.01, z (6917)=-0.02, p=0.985), and response accuracy was higher in the predictable than in the unpredictable channel context (β=-0.27, SE=0.14, z (6917)=-2.02, p=.043). We speculate from these observations that when there is no trial-by-trial variation of the levels of spectral degradation, listeners adapt to speech quality at a long timescale (i.e., across the block); however, when there is a trial-by-trial variation of the high-level semantic feature (e.g., sentence predictability), listeners do not adapt to low level perceptual property (e.g., speech quality) at a short timescale (i.e., trial-by-trial learning). Taken together, these findings support the probabilistic prediction account of language processing adding a novel insight in the case of degraded speech comprehension, and also shows the probable effect of high-level semantic feature of language in adaptation to low-level sensory characteristic of speech. and also shows the probable effect of high-level semantic feature on adaptation to low-level sensory characteristic of speech.

Topic Areas: Speech Perception; Perception: Speech Perception and Audiovisual Integration

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Pre-target alpha power predicts comprehension and subjective clarity of Digits-in-Noise

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The resting brain is never static and the ongoing changes in its underlying activity are thought to drive variability in cerebral and behavioural responses to stimuli. It has been shown that intra-individual differences in performance on a variety of auditory tasks, such as near-threshold stimulus detection, pitch discrimination and syllable identification are subject to influence from pre-stimulus brain states. Here we examine the relevance of pre-stimulus brain activity in noisy speech comprehension. Thirty-two normally-hearing participants (mean age = 24y, 26f) took part in an EEG recording (128-channels) during which they performed a digit in noise recognition task. Stimuli were monosyllabic German digits embedded in speech-shaped noise (SSN). Participants rated their subjective impression of clarity after responding to each digit. Digits were preceded by a 3.4 to 6 second-long segment of SSN. They were presented at three signal-to-noise ratios (SNR), individually calibrated using an adaptive staircase procedure achieving 50% accuracy. An easier and a harder condition were created by respectively increasing and decreasing the SNF by 1.5dB. The pre-stimulus (noisy) time window was analysed to determine whether there is a relationship between pre-stimulus activity and subsequent performance, which would be potentially indicative of the engagement of an auditory noise-suppression mechanism. EEG signals were converted to frequency-specific, time-resolved power using Morse wavelets with frequencies sampled logarithmically between 1 and 48Hz. Preliminary analyses (differences in pre-stimulus power averaged over correct and incorrect responses) indicated that a power difference in the α band (8-12Hz) was associated with accuracy at multiple sensors. A univariate mixed-effect logistic regression at the sensor level was used to test the hypothesis that pre-target α power, averaged in 50ms time bins between -500ms and digit onset, and across channels, predicts comprehension or subjective clarity on a trial-by-trial basis. We found that enhanced pre-stimulus α activity is associated with a higher probability of correctly recognising the target digit and associated with a higher subjective clarity rating. Specifically, comprehension is significantly related to α power within a frontal left-lateralised cluster of sensors between -450 and -300ms, whilst subjective clarity is associated with α activity within a left-lateralised temporo-parietal cluster of electrodes between -350 and -150ms. Thus, the ongoing pre-stimulus EEG activity in the face of ongoing noise can predict variation in SiN recognition. The topography of the results suggests that subjective clarity might relate to trial-to-trial variability in auditory attention, whilst comprehension might reflect fluctuations of top-down control on downstream auditory areas. Existing data suggest that reduced pre-stimulus α activity indexes enhanced excitability and results in the cortex being generally more susceptible to input, thus determining more frequent reports of stimulus presence (including false alarms) and higher levels of confidence in the perceptual decision. The association between increased α activity within the noisy pre-stimulus period and performance observed here might be understood in terms of a reduction in cortical excitability, effectively acting as a filter to avoid perceptual over-representation of noise, while leading to enhanced representation or detectability of the signal of interest.

Topic Areas: Speech Perception; Perception: Auditory

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The syllable we hear during binaural integration is represented in non-auditory cortical areas

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Binaural integration may arise during dichotic listening, when acoustically different stimuli are presented to each ear. Under some circumstances, binaural integration results in an auditory percept that is not physically present in either of the auditory stimuli. Here, we use fMRI and multi-voxel pattern analysis (MVPA) to address the question of where in the cerebral cortex syllable percepts emerge during binaural integration. Twenty-seven right-handed listeners with no history of hearing impairment (M=21.89 years, SD=3.14, 8 male) took part in an fMRI study in which one ear was presented with an ambiguous syllable (intermediate between /da/ and /ga/) and the other with an acoustic feature (third formant, F3). The contralateral F3 could be low (2.5kHz, consistent with /ga/) or high (2.9kHz, consistent with /da/). If dichotically presented information is binaurally integrated, the F3 biases the perceived syllable. Participants reported on every trial whether they heard a /da/ or a /ga/ syllable. In each of four fMRI runs (~7min each) participants heard 30 high and 30 low F3 dichotic stimuli as well as 24 unambiguous control stimuli (12 times /da/ and 12 times /ga/). In unambiguous control stimuli, a clear syllable was presented to one ear and the F3 consistent with this syllable was presented to the other ear. Hence, unambiguous control stimuli could be readily interpreted based on monaural input. We used an MVPA searchlight analysis (radius 8mm, 251 voxels, constrained to areas significantly responding to sound at the group level, p<.001 uncorrected) to identify brain areas in which there is a consistent differentiation in response pattern as a function of syllable report, that generalizes across unambiguous and ambiguous stimuli. Representational consistency was evaluated using the cross-valdiated mahalanobis (crossnobis) distance. Group-level permutation analysis revealed a number of clusters that consistently differentiate the reported syllable in both unambiguous stimuli and binaural integration stimuli. We find that BOLD activity patterns in the left anterior insula (AI), the left supplementary motor cortex, the left ventral motor cortex and the right somatosensory cortex (M1/S1) represent the syllable report of the participant. However, these categorical response patterns could be driven by the stimulus acoustics, the syllable percept, or both due to the confounding of the physical stimulus characteristics and perceptual interpretation. In follow-up analyses, we tested whether these regions carry information about the syllable percept (/da/ vs /ga/ response) alone, or rather the stimulus acoustics (high vs low F3) by recomputing the crossnobis distances between syllable reports within each stimulus class (high/low F3) alone. The converse was also calculated – the distance between each acoustic stimulus, within each syllable report (/da/-/ga/). In both cases the distances were cross-validated as previously, against the syllable reports in unambiguous stimuli. Larger crossnobis distances were found in the aforementioned areas between different syllable percepts than stimulus acoustics. The same areas have been previously implicated in perceptual decision-making (AI), response selection (SMA), and response initiation and feedback (somatosensory cortex). Our results indicate that the construction of the syllable percept during binaural integration occurs mainly in brain regions beyond the auditory cortex.

Topic Areas: Speech Perception; Perception: Auditory

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N400 modulations in metaphor processing and its associations with attentional systems: A behavioral and ERP study

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Although metaphoric language is one of the most common expressions of creativity in everyday life, the neurocognitive mechanisms underlying conventional and novel metaphors processing are not fully understood. In particular, the role of attention in metaphor comprehension is lacking. The first aim of the current study was to explore the nature of the N400 event-related potential (ERP) component in metaphor processing. The N400 is thought to reflect an online neurocognitive measure of semantic integration in the brain. The second aim of this study was to investigate whether the processing of conventional and novel metaphors is related to different attentional systems. Twenty-three students from Bar-Ilan university performed a metaphor novelty assessment (MNA) task while ERPs were recorded. In this task, participants were presented with expressions (e.g., feeling sad is like crying a river) and were asked to decide how creative and novel is each expression. In addition, a short version of the attention network test (ANT) was administered to investigate three attention networks, alerting, orienting, and executive control. The behavioral results of the MNA task showed that novel metaphors were rated slower and as more novel compared to the conventional metaphors. The ERP parameters indicated that for the novel metaphors, the N400 amplitudes were enhanced and peaked later compared to those produced by the conventional metaphors. Moreover, conventional metaphor processing was associated with the orienting attentional system, while novel metaphor processing was associated with executive control and the alerting system. The findings are discussed in terms of different cognitive demands on conventional and novel metaphor processing, and that different attentional systems may contribute to the processing of the two metaphor types.

Topic Areas: Speech Perception; Meaning: Lexical Semantics

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ERP and time-frequency correlates of phonological and temporal deviants in dyslexic readers

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Developmental dyslexia is a reading deficit of neurobiological origin, associated with persistent difficulties in fluent word recognition and impaired spelling abilities. Further deficits in speech processing are reported, with dyslexic individuals showing decreased sensitivity to sublexical features. In typical development, the brain exploits phonotactic and temporal regularities in speech through statistical learning, to achieve accurate phonological representations. These representations are crucial in early word learning, and may further contribute to reading development. The passive oddball paradigm offers an opportunity to study implicit processing of these features. The ERP component of interest is the mismatch negativity (MMN), a marker of experience-dependent change detection. Prior research has shown a sensitivity of the MMN to variations in phonotactic probability (Bonte et al., 2005) but not syllable stress (Emmendorfer et al., 2020) in Dutch speakers. This sensitivity is reduced in adults (Noordenbos et al., 2013) and children (Bonte et al., 2007) with dyslexia. In the time-frequency domain, auditory change detection is associated with increased theta inter-trial coherence (ITC) in deviant trials (Fuentemilla et al., 2008). Prior research has reported a further enhancement of theta ITC in children with dyslexia (Halliday et al., 2014). We used EEG to investigate the sensitivity to phonotactic and temporal regularities in speech in adults (aged 18-30) with and without dyslexia in a passive, multi-feature oddball paradigm. We manipulated phonological and temporal regularities in Dutch pseudowords varying in phonotactic probability (formal deviant) and syllable stress (temporal deviant). Each stimulus was presented as a formal deviant, temporal deviant, or standard. This allowed comparing identical stimuli across conditions. To understand the mechanisms underlying formal and temporal change detection, we perform both ERP and time-frequency analyses. ERP analyses revealed that both formal and temporal deviants elicit an MMN. For formal deviants, phonotactic probability modulates MMN latency, with high phonotactic probability deviants eliciting an earlier MMN compared to low phonotactic probability deviants, indicating facilitated change detection. These responses were overall delayed in dyslexic readers. We did not observe modulations of MMN in temporal deviants. In the time-frequency domain, we observed the typical increased theta ITC in formal deviants, with a trend towards enhanced ITC in dyslexic individuals. The theta ITC was modulated by syllable stress: Formal deviants with second syllable stress elicited greater theta phase-locking. Temporal deviants elicited decreased delta/theta ITC. The current results indicate an overall increase in theta ITC and slower ERP responses to formal deviants in dyslexic readers, but no group differences related to sublexical regularity. They support prior evidence of MMN sensitivity to phonotactic probability. The fact that we do not report group differences for phonotactic probability may be explained by comparably high reading levels of dyslexic university students. The dissociable oscillatory patterns observed for formal and temporal deviants are striking. As the acoustic markers of syllable stress are typically associated with increased theta ITC, the current pattern of oscillatory results may suggest that temporal deviants disrupt the tracking of the regular speech rhythm within a stimulus sequence, while change detection in formal deviants is associated with sensory memory processes.

Topic Areas: Speech Perception; Disorders: Developmental

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Human cortical encoding of vowels

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Introduction: Understanding natural speech requires listeners to map the continuous acoustics of vowel sounds onto discrete categories, a process that includes compensating for variability within and across speakers, such as due to different co-articulatory contexts or voice height. Vowel identity is determined by the central frequencies of the first two peaks in the vowel spectrum, called first (F1) and second (F2) formants. For example, /u/ and /i/ have similarly low F1 frequencies but differ in F2. Behaviorally, the influential perceptual magnet theory posits that the cognitive representation of vowels non-linearly warps the continuous F1-F2 acoustic space towards the prototypes of each vowel category. At the neural level, it has been suggested that human speech cortical areas on the superior temporal gyrus (STG) represent the relative spectral location of F1 and F2. It remains unclear, however, how such a representation may support the perception of vowel categories. Here, we capitalized on the high spatial and temporal resolution of high-density intracranial recordings (ECoG), to study how local neural tuning and distributed population representations in the STG represent vowels, using natural speech and artificial vowel sounds. Experiment 1: In Experiment 1, native speakers of Spanish (n = 7) listened to Spanish sentences naturally produced by a variety of speakers, while we recorded neural activity from the STG. First, we found that local neural populations (recorded at a single electrode contact) represented either one or both formants, with joint encoding of both formants on the majority of contacts. Formant tuning followed a nonlinear sigmoidal pattern, resulting in sensitivity to a subdivision of a formant's full range. Further, these representations shifted to normalize for differences between speakers with different voice heights. Decoding analyses show that local populations cannot reliably discriminate between vowel categories. Crucially, however, at the population level, the range of local co-encodings of F1 and F2 allowed for tuning to single vowel categories. Moreover, population-level responses to tokens from the same category clustered together, as predicted by the perceptual magnet theory. Experiment 2: The limited vowel formant space of natural speech did not allow asking whether this STG code is specific to speech sounds, nor comprehensively describing the range of joint formant encodings in STG. To address this, in Experiment 2, participants (n = 8) listened to artificial vowel sounds with formant combinations ranging beyond those encountered in natural speech. We found that the neural representation of formants extended beyond the natural vowel formant space. Moreover, local neural tuning was best described by two-dimensional formant receptive fields, encoding a wide range of combinations of F1 and F2 values, including but not limited to the distance between F1 and F2. Conclusions: Our results show that vowel-discriminating neural populations on STG are characterized by complex, nonlinear two-dimensional formant receptive fields. In human speech, this representation gives rise to the discrimination between vowel categories and sensitivity to their boundaries at the population level. Taken together, this work describes the neural computations in human STG that give rise to the perception of vowel categories.

Topic Areas: Perception: Auditory; Speech Perception

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Comprehension-relevant speech tracking in the auditory cortex and beyond

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Cortical tracking of continuous speech is a ubiquitous process that can be seen across different timescales and across many different brain areas. Less comprehensible speech is generally associated with weaker tracking, but the exact contributions of tracking at different linguistic timescales (words, syllables, etc) and in different areas remain elusive. I will first present evidence showing that it makes sense to differentiate between “general tracking” and tracking that influences our comprehension. Here, we used a single-trial approach to measure individual speech-in-noise comprehension of sentences. We found that the auditory cortex tracks speech faithfully at all timescales, but this does not necessarily influence our comprehension. Comprehension was only predicted by tracking in higher-level mid-temporal areas at the word rate, and motor areas at the phrase rate, respectively. This likely depended on the used behavioural task. The idea that not all low-level representations are behaviourally relevant is also supported by a decoding study on auditory and visual speech (lip reading) comprehension. Here we showed that speech representations were overall widespread, but that those few regions that showed comprehension-relevant representations of speech were relatively distinct for auditory and visual modalities. Extending this idea of general vs behaviourally-relevant tracking to music, I will also show that tracking in frontal areas predicts beat perception (finger-tapping performance), whereas tracking in putative low-level auditory areas does not. Taken together, these findings demonstrate that it is useful to include a behavioural task when analysing speech (and music) tracking, to disentangle general processes and those that predict behaviour and comprehension in a given task.

Topic Areas: Perception: Auditory; Speech Perception

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Neural Decoding of Concurrent Speech: Lessons from Selective and Divided Attention

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It is widely assumed that when individuals apply selective attention to a single speaker in a Cocktail Party setting, other so-called “task-irrelevant” speakers are ignored. However, the extent to which task-irrelevant speech is processed and the nature of its neural representation remains a highly debated topic. This ambiguity is further extended when considering how attention might operate under naturalistic conditions, where it might not always be beneficial to fully tune-out task-irrelevant speech. Some have suggested that natural listening in multi-speaker contexts might involve dynamic attention-switching between relevant and irrelevant speakers, rather than exclusive attention only to the relevant speaker. However, this hypothesis is extremely difficult to test experimentally, given the limited empirical access to the listener's internal state in selective attention paradigms. To circumvent this methodological challenge, here we explicitly manipulated the task-relevance of concurrently presented speech and examined how this affects its neural encoding in the brain. Specifically, we compared neural speech-tracking of two natural speech streams when only one was task-relevant (Selective Attention) vs. when both were task-relevant (Divided Attention). We recorded the magnetoencephalographic (MEG) response from 27 Hebrew native speakers, while they listened to two concurrent speakers telling short personal narratives (dichotic presentation). Before each trial, participants were either instructed to attend to one speaker (Selective Attention condition) or to both speakers (Divided Attention condition). After each trial, participants answered comprehension questions either about the pre-designated attended narrative (Selective) or about both narratives (Divided). Speech-tracking analysis was performed, allowing us to compare the neural representation of the acoustic envelope of both speakers. Subjects performed significantly better on the Selective Attention task (~89%) compared to the Divided Attention task (~72%), indicating that there is a behavioral cost to dividing attention. Speech-tracking analysis of the neural response to the two speakers replicated previous results of Selective Attention, with reduced responses to the task-irrelevant speaker vs. the task-relevant speaker in auditory regions. Interestingly, the neural representation of the two speakers in the Divided Attention condition was comparable to that of the task-irrelevant speaker in the Selective Attention condition. This pattern suggests that the partial encoding of task-irrelevant speech is akin to the encoding applied when attempting to divide attention among two speakers. We further characterize the neural results in terms of the degree of selectivity between the speakers and representation levels of both speakers, under these two attentional tasks. By contrasting these two opposing attention regimes, our results broaden the ongoing conversation about the system’s capacity and limitations for processing two speech inputs, and the dynamics of attention in ecologically valid settings.

Topic Areas: Perception: Auditory; Speech Perception

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Attentional Modulation of the Cortical Tracking of Acoustic Dimensions

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Many theoretical accounts of speech perception suggest that auditory dimensions that are strongly diagnostic for particular linguistic categories - for instance voice onset time or fundamental frequency in the case of some spoken consonants - attract attention. However, there has been relatively little research explicitly investigating whether this type of dimension-selective attention exists in the auditory domain. Here we investigate whether dimensional salience and dimension-selective attention modulate cortical tracking of acoustic dimension. In two experiments, participants listened to tone sequences varying in pitch and spectral peak frequency; these two dimensions changed at systematically different rates. Inter-trial phase coherence (ITPC) and EEG signal amplitude at the rates of pitch and spectral change allowed us to measure cortical tracking of these dimensions. In Experiment 1, tone sequences varied in the size of the pitch intervals, while the size of spectral peak intervals remained constant. Neural entrainment to pitch changes was greater for sequences with larger compared to smaller pitch intervals, with no difference in entrainment to the spectral dimension. In Experiment 2, participants selectively attended to either the pitch or spectral dimension. Neural entrainment was stronger in response to the attended compared to unattended dimension for both pitch and spectral dimensions. These findings demonstrate that bottom-up and top-down attentional mechanisms enhance the cortical tracking of different acoustic dimensions and provide the foundation for future research investigating the role of attention in speech perception.

Topic Areas: Perception: Auditory; Speech Perception

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Different listening strategies for natural speech in elderly: band-specific aging effects

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One recent advance in the field of neurobiology of language is to work with natural, connected speech. When listening to natural speech, the brain tracks the envelope of the stimulus, which contains important cues for speech understanding [1]. Research in healthy aging found, paradoxically, increased neural tracking of the envelope in elderly while speech understanding was decreased by aging [2,3]. These studies investigated the brain's response in a 1-8 Hz frequency range, containing both the theta and delta band. Disentangling these frequency bands might provide additional information, as they are believed to represent distinct processes. The timescale of the theta band corresponds to syllables and was found to uniquely contribute to acoustically processing the speech signal. The delta band on the other hand, encodes words and phrases and contributes more to actual speech understanding [4]. In the present study, we disentangled these frequency bands and separately investigated aging effects. Method: We did a re-analysis of previously published data demonstrating enhanced cortical tracking of natural speech in elderly (with a 1-8 Hz frequency band) [2]. 11 Young (17-37 yo), 32 middle-aged (42-60 yo) and 12 healthy older adults (62-82 yo) listened to a 15-minutes long story while electroencephalogram (EEG) was recorded. We calculated the mutual information (MI) between the speech envelope and the EEG data in the delta (0.5-4 Hz) and theta (4-8 Hz) bands. The MI can be considered as a measure of information sharing between two signals, with higher values reflecting a cortical response that is more tuned to the speech signal. This measure was recently applied in this field, demonstrating enhanced cortical responses for elderly with higher statistical power compared to linear methods [5]. Results: For the 1-8 Hz broadband signal, we replicated previous findings: a non-parametric cluster-based permutation test revealed a significant enhanced MI for older individuals in early processing stages (5-80 ms, $p = 0.029$). However, for the separate delta and theta bands a linear mixed effects model revealed a strong significant interaction effect between age and band ($F = 8.15$, $p = 0.006$). The MI was negatively correlated with age in the delta band (i.e., higher MI for younger individuals, Spearman's $R = -0.26$) and correlated positively with age in the theta band (i.e., higher MI for older individuals, Spearman's $R = 0.31$). Conclusion: The enhanced cortical response to natural speech stimuli is band-specific rather than generic. We therefore hypothesize that aging is accompanied by a shift in speech listening strategy, with elderly relying more on acoustic cues of the stimulus. These results can be integrated with recent work demonstrating that enhanced cortical tracking originates from an early acoustic response in the auditory cortex [3] and work reporting decreased cortical responses to language features at the semantic level in elderly [6].

Topic Areas: Speech Perception; Methods

Slide Slam F11 Play Video View PDF

When and when interactions during speech tracking

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Speech tracking is benefited by pro-actively predicting the timing and content of speech. There are models explaining how the brain tracks temporal structure in speech (when) and models explaining how the brain computes which speech units are coming next (what). So far, these theoretical accounts have been living in relatively independent worlds, seemingly to imply that what and when can be treated as two independent processes. I will argue that this implicit assumption is incorrect. Firstly, temporal speech dynamics are dependent on speech content. Secondly, the efficiency of brain processing changes as a function of the predictability of speech content. When taking this what/when dependency into account isochronous oscillatory dynamics can track naturally-timed speech. I will demonstrate this with computational modelling as well as with experimental behavioral and neuronal data. The results reveal that speech tracking entails an interaction between oscillations and predictions flowing from internal language models.

Topic Areas: Speech Perception; Computational Approaches

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Rapid pre-attentive voice recognition of a famous speaker: Electrophysiological effects of Angela Merkel's voice

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Introduction: The recognition of human speakers by their voice is a remarkable cognitive ability with parallels to human face recognition. Previous research has established a voice area in the right temporal cortex that helps extracting relevant acoustic features while listening to speech. The integration of these features appears to be accomplished rapidly, indicating a pre-attentive processing of voices. With contrasting brain responses to familiar and unfamiliar voices, a previous MMN (Mismatch Negativity) study reported an effect of voice familiarity and recognition on general voice processing: stronger activations were generated by familiar voices. The familiar voices used for this study were extracted from the participants' personal environment. The present study aims to further investigate this effect for publicly but not personally known voices. Therefore, the voice of German chancellor Angela Merkel was contrasted with acoustically matched-voices while an electroencephalography was carried out to record the correlating neurophysiological patterns. Method: A classic passive oddball paradigm contrasted two two-syllable German utterances (Kinder 'children' and Tochter 'daughter') by Merkel with the same words uttered by two unknown female speakers with matched voice characteristics (age, regional background and voice quality). As Merkel has been in office for over 15 years, it can be assumed that she should be easily recognized by German listeners. Twenty-one participants (21-43y) were presented with standard-deviant trains of these word stimuli while their electroencephalogram was recorded from 32 active electrodes. Electrophysiological voice processing indices were quantified as identity mismatch negativities (MMNs) and P3 differences, and cortical sources of both difference wave forms were estimated with variable resolution electromagnetic tomography. Results: The results showed amplitude and latency effect for both MMN and P3: Merkel's voice elicited a smaller but earlier MMN than the control voices. The P3, by contrast, was both larger and later in response to Merkel. Importantly, the MMN amplitude effect depended on speaker recognition. Recognition could be predicted by MMN amplitudes and participant age. Younger participants' recognition was indexed by higher amplitudes, while older participants' recognition was indexed by lower amplitudes. Finally, the MMN in response to Merkel originated from right-hemispheric regions in temporal cortex, overlapping with the voice area, while the MMN in response to the controls originated from left superior temporal gyrus. P3 responses to Merkel had sources in left superior temporal and middle frontal gyrus, while P3 responses to the controls had sources in right temporal and occipital areas. Conclusion: These results suggest unique recognition patterns of very famous voices by electrophysiological responses. Speaker recognition by voice seems thus to rely on pre-attentive right temporal processing within the first 150 ms of the acoustic signal. Further, the amplitude reduction in response to Merkel's voice is compatible with predictive coding accounts that assume reduced prediction error if there are strong priors.

Topic Areas: Speech Perception; Perception: Auditory

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The influence of 2kHz Transcranial Alternating Current Stimulation (tACS) over the articulatory motor cortex on cortical excitability and categorical perception of speech sounds

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Although the ventral motor cortex (vMC), the area in which the neural representations of the articulators are, is activated during speech perception, the functional role of this activation remains unclear. Previous studies reported that the inhibition of this region with repetitive transcranial magnetic stimulation (rTMS) impairs categorical speech sound perception. Moreover, listening to speech sounds has been shown to facilitate cortical excitability in this region. Based on this evidence, we hypothesized that enhancing cortical excitability in this area would increase categorical speech sound perception. For this purpose, high frequency (2kHz) transcranial alternating current stimulation (tACS) was applied over the left ventral motor cortex to enhance cortical excitability. The cortical excitability of the left vMC was assessed before and after tACS, by measuring the amplitude of motor evoked potentials (MEPs) elicited by monophasic single pulse TMS. The MEPs were recorded on the muscle orbicularis oris (OO) of the lips. Categorical perception of speech sound was assessed by a syllable identification and a syllable discrimination task. The presented syllables were part of artificial acoustic continua that either involve lip articulators (/ba/-/da/) or not (/ga/-/ka/). Such continua consist of eight steps that gradually vary and are typically perceived as one or the other. Thus, the continua can be divided into two discrete regions depending on the subjective perceived boundary. The identification task allows to analyse the individual category boundary by computing the individual psychometric curves. In the discrimination task, all subjects were presented two stimuli at a time, separated by two steps of the continua (1-3, 2-4…). Depending on the individual category boundary, the pairs were classified as across-category or within-category pairs. If the categorical perception is improved, a steeper slope and therefore clearer category boundary perception is expected in the identification task, whereas in the discrimination task a higher proportion of “different” responses in the across-category pairs (pairs containing the individual boundary) is expected. The analysis of the neurophysiological data revealed no significant effect of high frequency tACS on lip motor excitability, contrary to expectations based on the literature. Further, tACS did not significantly modulate syllable identification and discrimination performance. Thus, no significant change in categorical speech sound perception could be observed. Overall, our results indicate that the 2 kHz stimulation does not reliably modulate cortical activity. In a next step, we will thus collect a new dataset applying random noise stimulation (tRNS) to the left vMC. Recent studies suggest that tRNS is more effective in enhancing motor cortical activity than kHz tACS.

Topic Areas: Speech Perception; Methods

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Influences of inhibitory TMS over visual area V5 on visual speech recognition

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The middle temporal visual area (V5) plays a critical role in the perception of low level motion stimuli such as random dot patterns, supported by studies using transcranial magnetic stimulation (TMS; e.g., Beckers & Zeki, 1995). In addition, functional magnetic resonance imaging (fMRI) studies demonstrate V5 responses to the rather complex biological motion that characterizes visual speech (Borowiak et al., 2018). However, whether there is a causal influence of V5 on visual speech recognition remains unclear. Here, we investigated the contribution of V5 to visual speech recognition (lip-reading) by using neuronavigated TMS on area V5, for which the coordinates were previously acquired with an fMRI localizer. 24 participants underwent offline continuous theta burst stimulation over bilateral V5 in one session, and over the vertex as control site in another session. Subsequently, we administered a visual speech recognition task and a motion direction (control) task using random-dot kinematograms. There are two main results. First, we found that TMS on V5 increased response times compared to the stimulation over the vertex region in both tasks. Second, there was no significant interaction of stimulation and task, indicating that there was no substantial difference of stimulation on the response times in motion-direction and visual-speech recognition. We conclude that the area V5 not only contributes to low-level motion recognition mechanisms, it also plays a role in the processing of complex visual human communication signals.

Topic Areas: Speech Perception; Methods

Slide Slam F16 Play Video View PDF

Enhancement of speech-in-noise comprehension through transcranial alternating current stimulation

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Auditory cortical activity tracks speech rhythms, in particular at the rate of words (1 - 4 Hz, delta band) and at the rate of syllables (4 - 8 Hz, theta band). The modulation of this cortical tracking through alternating current stimulation with the speech envelope has been found to influence the comprehension of speech in noise. However, the stimulation can be performed with different parameters, such as temporal delay, particular frequency band and a potential phase delay. The influence of these stimulation parameters on speech comprehension remains insufficiently understood. We presented human volunteers with single sentences that were embedded in noise to assess their speech comprehension. Simultaneously we stimulated the subject's auditory cortices through transcranial alternating current. The current waveforms were obtained from the speech envelope and were shifted by different temporal delays as well as phases. We also explored currents that were obtained from the speech envelope filtered in the delta and in the theta frequency bands. We first investigated two characteristic delays that emerge in the cortical tracking of speech rhythms, a short delay of 100 ms and a longer delay of 250 ms. We found that current stimulation at both delays influenced speech comprehension. Next, we applied current waveforms that followed either the delta- or the theta-band portion of the speech envelope. The theta-band current stimulation had a significant effect on speech comprehension, while the delta-band stimulation did not. We further investigated the influence of different latencies of the theta-band stimulation on the comprehension of speech in noise. We found that a latency of 0 ms yielded the highest speech comprehension, which was higher than under a sham stimulus. Last but not least, we showed that stimulation with the envelope of a distractor speaker could modulate spech comprehension as well. Taken together, our results demonstrate that the modulation of speech comprehension through transcranial alternating current stimulation is driven by the theta- but not by the delta band. Speech-in-noise comprehension can be enhanced when the current waveform is temporally aligned to the speech signal. Moreover, the delta rhythms of a distractor speaker appear to be processed in the brain as well, presumably competing with the processing of the target speaker.

Topic Areas: Speech Perception; Perception: Auditory

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Motor planning of speech and of uncommonly produced non-speech gestures

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The relationship between speech and other types of oromotor behaviors is a matter of debate in the literature. Some authors propose a specialized motor control system for speech (Ziegler et al., 2003) whereas some others suggest a general motor system shared for speech and other related motor tasks (Ballard et al., 2003). In a previous study, we investigated whether the motor planning of high and low frequency syllables activated the same neurophysiological networks involved in planning the motor codes of commonly produced non-speech sequences (Lancheros et al., 2020). Results indicated recruitment of the same neural networks but they were differently involved, especially in the motor planning of high frequency speech items relative to commonly produced non-speech gestures; infrequent syllables were found to be somehow intermediate between those two types of stimuli. In the present study, we aim to investigate the neural correlates of rarely produced non-speech gestures by means of high density electroencephalographic (EEG) evoked response potentials (ERPs). Uncommon non-speech gestures are issued from a pilot study in which participants were asked to rate at what frequency they have heard/produced a bunch of sounded orofacial movements presented in short video clips. The less common non-speech gestures were chosen (n=18) and they were carefully matched, in terms of acoustic and somatosensory targets, to high and low frequency syllables. The three types of stimuli were presented to participants in a delayed production task, where speakers prepare an utterance, but produce it overtly after a short delay. This type of task allows targeting the "latest" production stages, where the linguistic message is transformed into the corresponding articulated speech. Preliminary results on 10 participants show significantly longer reaction times for uncommon non-speech gestures as compared to high frequency syllables, whereas no differences are found between the production of uncommon non-speech gestures and low frequency syllables. As concerning the ERP results, they reveal the same global electrophysiological patterns across conditions on the stimulus locked ERPs. Regarding the latest stages before articulation in response-locked ERPs, significant differences in the distribution of the same microstates are found between uncommon non-speech gestures and both high and low frequency syllables in a time-window extending from -50 to -275 ms relative to the vocal onset. Those results are consistent with previous findings, suggesting that motor planning of uncommonly produced non-speech gestures recruit the same brain networks of high and low frequency syllables, but those networks are differently involved. What remains surprising though is that the mentioned differences in response-locked ERPs are present in a standard delayed production task, in which neither behavioral nor neural differences are expected during pre-articulatory processes. In fact, since participants are given the time to retrieve/prepare the motor codes of each stimuli during the delay, they are expected to launch the previously retrieved/prepared speech and non-speech motor plans in a similar way once the response cue is presented. Those results need to be compared to a delayed production task combined with an articulatory suppression task, for which we are currently collecting the data.

Topic Areas: Speech Motor Control; Language Production

Slide Slam G2 Play Video View PDF

Synchronised speech and speech motor control: convergence in voice fundamental frequency during choral speech

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Synchronised speech behaviours such as choral speech (speaking in unison) are found in a variety of everyday settings, and have clinical relevance as a temporary fluency-enhancing technique for people who stutter. It is currently unknown whether such synchronisation of speech timing among two speakers is also accompanied by alignment in their vocal characteristics, for example in acoustic measures such as pitch. The current study investigated this by testing whether convergence in voice fundamental frequency (F0) between speakers could be demonstrated during choral speech. Sixty participants across three online experiments were audio recorded whilst reading a series of sentences, first on their own, and then in synchrony with another speaker (the accompanist) in a number of between-subject conditions. Experiment 1 demonstrated significant convergence in participants' F0 to a pre-recorded accompanist voice, in the form of both upward (high F0 accompanist condition) and downward (low F0 accompanist condition) changes in F0; however, upward convergence was greater than downward convergence. Experiment 2 found that downward convergent changes in F0 could not be increased by the use of an accompanist voice with an even lower F0. Experiment 3 demonstrated that such convergence was not seen during a visual choral speech condition, in which participants spoke in synchrony with silent video recordings of the accompanist. Further, convergence in F0 was enhanced for a condition where participants could both see and hear the accompanist in pre-recorded videos compared to synchronisation with the pre-recorded voice alone. These findings suggest the need for models of speech motor control to incorporate interactions between self- and other-speech feedback during speech production, and suggest a novel hypothesis for the mechanisms underlying the fluency-enhancing effects of choral speech in people who stutter.

Topic Areas: Speech Motor Control; Multisensory or Sensorimotor Integration

Slide Slam G3 Play Video View PDF

An integrated approach to speech and silence: Combining linguistic, neuropsychological, and anatomical data

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This study investigated pause-related variables and speech/articulation rate (henceforth SR and AR) in two different speech genres, in healthy individuals. Our aim was threefold. First to investigate whether SR and AR, as well as silent pauses’ frequency and duration significantly differ in two narrative tasks. Then, to explore whether silent pauses’ frequency is related to performance in specific neuropsychological tests. Finally, to assess the possible predictive value of anatomical indices for silent pauses’ duration for each narrative task. Sixty-five neurotypicals (33 males), 25–65 years old, right-handed, monolingual Greek, were recruited. Speech elicitation tasks consisted of a personal story narration and a picture description. Speech samples were analyzed and AR, SR, silent pauses’ frequency and duration were calculated. All participants underwent a neuropsychological assessment, including language, verbal memory and short/working memory tasks. Neuropsychological scores derived from participants’ assessments were entered into a PCA with Promax rotation to reduce the number of neuropsychological scores. 3D-T1w and DTI images were acquired. T1s were analysed using Free surfer and DTI following the global tractography approach, DTI&Fibertools toolbox. GLM models indicated that articulation rate remains stable across narrative tasks, while speech rate is significantly increased in picture description [$t(64)=-2.02, p=.0476$], and pause frequency and duration are significantly increased in story narration [$t(64)=3.814, p=.00031$ and $t(64)=2.926, p=.00475$]. PCA analysis yielded a three-factor solution, interpreting 64.32% of variance in participants’ performance. The first (36.87%) included verbal learning tasks. The second (15.34%) contained verbal short-term/working memory tasks and the third (12.10%) included naming, receptive vocabulary, and semantic fluency. Exploratory regression models were conducted between factors’ individual values and total silent pauses’ frequency, pauses prior to nouns and prior to verbs, separately for each speech genre. The only significant model was for silent pauses prior to nouns from picture description [$F(6,64)=3.258, p=.008$], as it predicted 25% of the variance ($R2=.252$). Within this model, only the third factor appeared as a significant predictor ($\beta=-.5231, p=.00086$). Finally, separate linear mixed effects models were conducted for each speech genre including individual durations of silent pauses as dependent variables, cortical and white matter indices as factors and participants as random effects. The best fitting models for fractional anisotropy (FA) and tract volume included left arcuate, extreme capsule and middle longitudinal fasciculi, with demographics as covariates. Results for picture description indicated that FA [$t(51)=-2.770, p=.00782$] and volume [$t(49)= 2.532$, $p =.0146$] of the arcuate fasciculus can successfully predict pause duration. Extreme capsule’s volume could successfully predict pause duration [$t(50)=3.238, p=.00214$] for personal story. The best fitting model for picture description and cortical regions included the surface area of inferior parietal lobule, superior and middle temporal gyri, pars triangularis and opercularis and insula and revealed only pars opercularis as a significant predictor [$t(46)=-2.228, p=.0308$]. Pars triangularis had a significant effect [$t(60)=-2.097, p=.04020$] on silent pause duration for personal story. Overall, by combining linguistic, neuropsychological and anatomical data we argue that different narrative tasks may be associated with distinct aspects of cognition and brain anatomy in healthy individuals, and further support the notion that silent pauses’ may reflect underlying cognitive processes during speech flow.

Topic Areas: Language Production; Control, Selection, and Executive Processes

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Non-native noun phrase production: An ERP study on the role of language similarity

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Language similarity is a critical component in multilingual language acquisition and processing. For example, in native speakers or high proficient learners, languages from the same family have shown comparable brain activation patterns and faster response times compared to languages from different language families. In lower proficient multilinguals, these neural and behavioural effects were emphasized. At the root of language similarity effects is cross-linguistic influence (CLI), the interaction of the languages within a multilingual system. Here, the question arises whether CLI effects are more pronounced in linguistically similar vs. dissimilar language pairs in late language learners. In the current study, we explored CLI effects via the gender congruency effect and the cognate facilitation effect in two groups of late language learners of Spanish whose native language belonged to the same (Italian) or different (German) language family. We placed a special emphasis on the neural correlates of language similarity effects. More specifically, we explored the P300 effect as an index for conflict monitoring and inhibitory control, and the N400 as an index for language co-activation and CLI effects. We investigated naming latencies and EEG signal modulation during non-native noun phrase production (determiner + noun [la flor] “the flower”) in a “linguistically similar” group of thirty-three Italian late learners of Spanish and a “linguistically dissimilar” group of thirty-three German late learners of Spanish using an overt picture-naming task. First, we predicted faster naming latencies for congruent and cognate nouns compared to incongruent and non-cognate nouns across both groups, reflecting the interaction of the syntactic and phonological systems of the two languages. Next, we also predicted a P300 effect and an N400 effect to reflect the cognitive mechanisms underlying the mitigation of CLI effects. More specifically, for both groups we predicted less positive P300 amplitudes and less negative N400 amplitudes for congruent and cognate nouns compared to incongruent and non-cognate nouns. Second, for an effect of language similarity, we predicted larger CLI effects for the linguistically similar Italian-Spanish group compared to the German-Spanish group. Accordingly, at the neural level, we predicted larger P300 and N400 effects for the Italian-Spanish group compared to the German-Spanish group. Across both groups, we observed a gender-congruency effect and a cognate facilitation effect in the naming latencies. Language similarity, however, did not appear to influence naming latencies. In EEG terms, we found evidence for a P300 effect, but not an N400 effect in both groups. However, while P300 amplitudes were modulated by gender congruency and cognate status for the German-Spanish group, this was not the case for the Italian-Spanish speakers. This suggests an effect of language similarity reflected by larger P300 effects for the German-Spanish group compared to the Italian-Spanish group. Overall, our results suggest traceable CLI effects in late learners. Moreover, we found distinct neural signatures of mitigating CLI effects on the basis of language similarity. Our study has important theoretical implications for the role of linguistic similarity in non-native language production and for our understanding of non-native acquisition and production models in late language learners.

Topic Areas: Language Production; Multilingualism

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Frontal event-related potentials to self-produced foreign phonemes change as pronunciation improves

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When learning to pronounce a foreign phoneme, one needs to learn how to produce motor output that matches the target phoneme. This requires comparing the produced phoneme to a representation of the target phoneme and adjusting speech accordingly. Most previous brain research on phoneme learning has employed paradigms where participants solely listen to phonemes. Here, we were interested in how auditory event-related potentials (ERPs) to self-produced phonemes change during learning. We tested 20 Finnish participants who pronounced either familiar /ö/ phonemes or foreign Estonian /õ/ phonemes. In another experimental condition the participants passively listened to a playback of their own speech. Behavioral results showed that the participants' pronunciation of the foreign /õ/ improved throughout the experiment. Consistent with previous literature, the results showed that between 100–300 ms after sound onset, ERPs to self-produced phonemes were suppressed relative to the same phonemes when heard passively. This effect, known as the speaking-induced suppression, was similar for Finnish and Estonian phonemes and did not change during the experiment. In contrast, during a later time-window (350–500 ms), frontal ERPs to self-produced foreign /õ/ phonemes were selectively modulated throughout the experiment. This effect was not observed for Finnish /ö/ phonemes. This result suggests that the late frontal ERPs may reflect cognitive processes, such as metacognitive evaluation of pronunciation outcome, that mediate the process of learning to produce a novel phoneme.

Topic Areas: Language Production; Multisensory or Sensorimotor Integration

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Development of the relationship between spelling and motor control of handwriting : a coupled fMRI and kinematics study

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Recent research in adults demonstrated that processes underlying the orthographic and motor aspects of handwriting occur in parallel, and that orthographic processes influence motor processes. Here, we examined how this relationship evolves between middle-childhood and adulthood both at the behavioral and at the brain level. In the light of recent behavioral studies, we hypothesized that orthographic and motor processes occur in a more sequential and independent fashion in children, whose writing is not yet automatized. We designed an experiment where we coupled functional magnetic resonance imaging (3-Tesla MRI Scanner Magnetom-Prisma, Siemens, Erlangen, Germany; EPI sequence with TR= 957 ms, TE= 30 ms, voxel size= 2.5 mm3, multiband factor= 4, slices= 56) and kinematic recordings (MRI-compatible digitizing tablet) during a writing to dictation task (single regular and irregular french words, cursive or semicursive writing). We compared three groups of participants: 3rd grade children (8-9 years old, N = 18), 5th grade children (10-11 years old, N = 24), and adults (N = 26). We found an increase of writing duration and size for irregular compared to regular words in all 3 groups. This effect of regularity on writing was stronger for 5th grade children than for the other 2 groups. It is assumed to be a marker of the influence of spelling retrieval on motor processes. At the brain level, we computed statistical models that integrated the single trial behavioral data to target main effects of irregularity during handwriting execution. We evidenced stronger responses to irregular words in a distributed network including inferior frontal and ventral occipitotemporal regions known for their systematic recruitment for orthographic processing, and dorsal premotor and parietal regions known for their functional specificity to writing movements. This pattern of activation replicates previous findings. Together with the behavioral data, it suggests that spelling processes are active during the execution of handwriting and influence motor control in both adults and children. However, we also observed a more prefrontal distribution of irregularity processing in 5th graders, and a specific recruitment of the anterior cingulate cortex and caudate nucleus for irregular words in this age-group. Both regions belong to a network crucial for conflict monitoring and inhibition. Our results indicate that contrary to our expectations, children are able to process orthographic and motor information in parallel during writing. However, they also suggest that the relationship between orthographic and motor processes matures between 3rd grade and adulthood under the influence of domain-general prefrontal control mechanisms, with a crucial developmental window at age 10-11. These data contribute to our understanding of how writing skills become grounded in the brain.

Topic Areas: Language Production; Development

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The development of referential and inferential naming: behavioural and spatio-temporal dynamics

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Changes in word production occur across the lifespan. Previous studies have shown electrophysiological, temporal, and functional differences between children and adults accompanying behavioural changes in referential word production -picture-naming tasks - (Laganaro et al., 2015), with a completely adult-like pattern observed only in 17-year-old adolescents (Atanasova et al., 2020) and an intermediate pattern between children and adults in adolescents aged 14 to 16 years old. In these studies, electrophysiological changes from childhood to adulthood were circumscribed to an early time-windows, around 170 ms after the presentation of the visual referent, which has been associated with pre-linguistic (conceptual) processes in referential word production (Indefrey. 2011). The question of which pre-linguistic processes are involved in the said maturation is still to be answered, in particular because the referential task involves a specific visuo-conceptual process, which may be the one carrying the observed maturational changes. To answer this question, we turned to an inferential production task – naming from auditory definitions - , involving different conceptual to lexical processes. Behaviour and event-related potentials (ERP) in a referential word production task and an inferential word production task were recorded and compared in three groups of adolescents (respectively aged 10 to 13, 14 to 16, and 17 to 18). On both tasks, the two oldest groups of adolescents displayed similar production latencies, which were longer only for the youngest group, while accuracy was lower in the youngest adolescent group compared to the two older groups. ERP waveform analysis and topographic pattern analysis revealed significant intergroup differences in key time-windows on stimulus-locked ERPs on both tasks. The microstate analyses indicate that there are group differences in the brain activation underlying inferential word production. Thus, the changes across ages observed in a referential task are not merely linked to the visual-conceptual processes in the pre-linguistic stages of a picture naming task but are rather related to semantic processes involved in word production.

Topic Areas: Language Production; Development

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ERP correlates of new word with an immersive virtual reality

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Learning new words is a very well-trained ability of the human cognition, which event adult speakers perform almost every day. In an educational or therapeutic context, new technologies allow to learn new words effectively. New technologies, such as virtual reality, are emerging and the range of assessment, rehabilitation or learning possibilities they offer leads to the necessity to assess their efficiency and possible advantages on the processing underlying word learning and word production. A clear advantage of virtual reality is the possibility to introduce a communicative and semantic context closer to everyday conversations (Repetto, 2014 ; in aphasia : Cao and al., 2021 ; Repetto and al. , 2020 ; in second language learning : Legault and al., 2019), while in other contexts new-word learning may rely on simple associations between an object/concept and its label, as suggested in previous word learning studies (see Fargier and Laganaro, 2020). Therefore, the aim of the present study is to determine whether new words learnt with an immersive virtual reality system lead to better lexical-semantic integration relative to learning in a standard object-word association setting both at a behavioral and electrophysiological event-related (ERP) levels. 20 young neurotypical adults leaned 2 lists of 40 new words (very low frequency real words) matched on relevant psycholinguistic variables (frequency, number of phonemes, phonological neighborhood, and so on) belonging to four semantic categories and that have been validated as unfamiliar using an online pretest (max naming rate 22%). In two different days over a week period, learning was carried out tanks to an immersive VR that consists of a market scenario in which participants have to search for objects by asking avatars or with a more standard tablet application. Behaviour and EEG recording was performed at baseline and after each learning period with a picture naming task and picture-word semantic interference task. Analyses are in progress. Behaviourally we expect better performance and larger PWI semantic interference on items learnt with immersive virtual reality. ERP signal in the picture naming task should differ qualitatively (different microstates) between the list of words learnt with VR relative to standard learning in a time-window associated with lexical-semantic processes, the former being closer to the production of well-known words. If such differences are observed source localization analysis will be performed in order to determine which brain region carry such difference. To conclude, this project will allow to better understand the benefit that virtual reality can provide in the lexical-semantic integration of new word learning field.

Topic Areas: Language Production; Meaning: Lexical Semantics

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Web-based Language Production Experiments: Semantic Interference Assessment is Robust for Spoken and Typed Response Modalities

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For experimental research on speech production, temporal precision and high quality of the recorded audio-files are mandatory. These requirements are a considerable challenge if speech production is to be investigated online. However, besides the current situation, online research has a huge potential regarding efficiency, ecological validity and diversity of study-populations in psycholinguistic and related research. Here, we supply confirmatory evidence that language production can be investigated online and demonstrate that written naming responses (using the computer keyboard) are a reliable and efficient alternative to typical overt spoken responses. To assess semantic interference effects in both modalities we performed two pre-registered experiments (n=30 each, sample sizes estimated using power analyses) in online settings using the participants' web-browsers. A cumulative semantic interference (CSI) paradigm was employed that required naming of several exemplars of semantic categories within a seemingly unrelated sequence of objects. Reaction time is expected to increase linearly for each additional exemplar of a category being named (Howard et al., 2006). In experiment 1, cumulative semantic interference effects in naming times described in lab-based studies were replicated. In experiment 2, the responses were typed on participants' computer keyboards and the first correct key press was used for reaction time analysis. This novel response assessment yielded a qualitatively identical, very robust CSI effect. We additionally compared automated data processing procedures, including accuracy assessment using string-matching metrices, and manual preprocessing procedures. Thereby we provide evidence that automated assessment of participants' accuracy in their typewritten answers can increase inter- and intra-rater replicability while considerably reducing the time needed to process such data prior to data analysis. Thus, besides technical ease of application, collecting typewritten responses and automated data preprocessing can reduce the work load for language production research. Results of both experiments open new perspectives for research on reaction time-sensitive effects in language experiments across a wide range of contexts, including cross-sectional or longitudinal studies which may have limited practicability in in-person, lab-based settings. Perspectively, employing speech production experiments in web-based settings may also open new possibilities to test participants with an acquired language disorder (most notably, post-stroke aphasia), for which long-term follow-up, especially regarding scientifically motivated questions, is often hampered by the efforts related to re-inviting and transporting the patient to the respective institution. We highlight important technical and conceptual considerations for the planning stages, response time assessment, and data analysis. Hereby, we hope to provide recommendations for an easy access to studying both typewritten and spoken language production online. JavaScript- and R-based implementations for reaction time assessment and data processing are available for download.

Topic Areas: Language Production; Methods

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Brain oscillations and microstates: a new way of analyzing ERP data. An example applied to a verbal Stroop task

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Introduction: investigating neural activity in cognitive studies can be achieved by several different methods. Microstate analyses have been proven to be very helpful at disentangling the different brain network underlying a specific cognitive process and their time course (Murray et al., 2008) and have been applied in many studies on language. Microstates are obtained by segmenting the ERP signal in different periods of topographical stability. It is well established that a single topography can reflect a brain network composed of different structures, however the relationship between the topographies and the brain oscillations underlying these structures remained to be clarified. To investigate this link, a previous study performed a microstates analysis on EEG signal filtered in different narrow frequency bands (Férat et al., 2020). The results showed a good reliability of the microstates over the different frequency bands even though quantitative differences were observed. The present study aims at clarifying if the method is applicable to ERP signal and to estimate the reliability of the microstates in the different frequency bands. To obtain results comparable with a furnished literature, these analyses were performed on a verbal Stroop task. Method: 31 young healthy subjects performed a verbal Stroop task including 180 trials (60 congruent, 60 incongruent and 60 neutral trials) while undergoing a continuous EEG recording with 128 electrodes. To investigate the relationship between microstates and frequency bands, the raw signal was filtered to cover different frequency bands, namely: delta, theta, alpha, beta and gamma and the subjects' average ERPs were segmented using a TAAHC algorithm for each of the frequency band as well as for the broadband signal. Since the verbal response generates an artifact, analyses were carried on two alignment points: locked to the stimulus and locked to the response onset (backwards). Results: The microstates analysis on the broadband signal suggests that four topographies best explain the signal. Regarding the segmentation performed on data filtered in narrow frequency bands, the higher the frequencies, the more different the segmentation gets from the broadband signal. Delta and theta bands show globally comparable microstates (among conditions and frequency bands) while the signals filtered in the alpha to gamma bands are each best explained by two topographic maps characterized by an inversion of polarity. Discussion: these encouraging preliminary results tend to show that microstates on broadband signal is only a simplified version of the results merging several generators firing at different frequencies. By filtering the signal in frequency bands, subtle changes in the microstates could be highlighted, opening new perspectives in the field of neuroimaging. Moreover, by appreciating the duration or global explained variance of the microstates present in each of the conditions and frequency bands, it might become possible to single out brain networks related to the interference processing from those related to word production.

Topic Areas: Language Production; Methods

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Transcranial magnetic stimulation over the IFG facilitates action naming, but is modulated by language lateralization and handedness

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Neuropsychological studies suggest functional and neuroanatomical differences between noun and verb processing. Empirical data show that the inferior frontal gyrus (IFG) is specifically involved in action-related word processing. One vital question is whether the difference between verbs and nouns is conceptual or grammatical in nature. In the current study, we examined whether repetitive transcranial magnetic stimulation (rTMS) over the IFG would only influence verb production if a grammatical class is at stake, or would influence both noun and verb production, if it is involved in processing of action-related words. Healthy Russian adults (n = 31) with a different direction and degree of handedness, as measured with the Edinburgh Handedness Inventory, participated in the study. Handedness quotient (HQ) for each participant ranged from -100 to +100. Individual language-related functional activation maps and language lateralization were previously assessed in them in a functional magnetic resonance imaging (fMRI) study with a sentence completion task. Laterality indices (LIs) for functional maps were calculated with LI-Toolbox in SPM and ranged from -1(right hemisphere) to 1(left hemisphere). We applied rTMS over participants' left and right IFG, as well as sham vertex stimulation (control condition), in an object and action naming task. rTMS bursts were delivered for 1000 ms and 300 ms after an onset of the picture presentation. The task was to name an object or to say what a hero is doing in a picture, with one word. We fitted generalized (for accuracy) and linear mixed effect models (for log-transformed reaction times (RTs)) separately for nouns and verbs with stimulated site, HQ and LI as predictors. During stimulation over the left IFG, compared to the control sham condition, verbs were produced significantly more accurately ($p = 0.03$) and there were significant interactions between RTs, LI and HQ: increased LIs predicted decreased RTs ($p=0.03$) and increased HQ predicted increased RTs ($p < 0.01$) in action naming, while increased LI and increased HQ predicted increased RTs ($p = 0.03$) in object naming. After stimulation over the right IFG compared to the control condition we did not find the main effect of stimulated site, but several significant interactions were found: in object naming accuracy was significantly higher with increased LIs ($p < 0.05$), increased LIs predicted increased RTs ($p = 0.001$) and increased HQ predicted decreased RTs ($p < 0.001$); in action naming increased LIs and increased HQ predicted increased RTs ($p < 0.001$). The results demonstrate TMS-induced facilitation effect for action naming in the left IFG stimulation condition. The accuracy scores for object naming, as well as RTs for both action and object naming were affected by stimulation depending on handedness and language lateralization of our participants. Individuals with more left lateralized language representation were faster in verb production when the left IFG was stimulated. This result confirmed the specificity of the left IFG for processing verbs as a grammatical class. The hypothesis about involvement of these regions in processing of action-related words irrespective of their grammatical class was not confirmed.

Topic Areas: Language Production; Speech Motor Control

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Disentangling language production impairments in Parkinson’s Disease

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Parkinson’s Disease (PD) is a neurodegenerative disorder characterized by cardinal motor symptoms, including resting tremor, rigidity and bradykinesia, and cognitive impairments, such as deficits in executive function, attention and short-term memory. Beyond these issues, patients frequently report morphosyntax, lexical-semantic and word finding difficulties but the underlying nature of these deficits is not well understood. Verbal fluency is often used as a neuropsychological test to assess production impairments in PD, however, due to its time constraints, it puts extra demands on motor and executive functions, making it a less sensitive task to tap into language specific processes. Moreover, individuals with PD show a bigger impairment for action words with a high motor content (e.g., motor-related words like ‘walk’) than for other words, suggesting their production difficulties cannot be fully explained by motor and executive function impairments. Silent pauses in continuous speech, i.e., a period of non-speech within or between words that could coincide with inhalation, have been suggested to reflect cognitive mechanisms underlying language production. Pauses are often located at syntactic boundaries (e.g., “she pets the dog [pause] of her friend”), but can also occur at non-syntactic boundaries (e.g., “she pets the [pause] dog”), such as within phrases. More pauses and/or longer pauses might suggest either a conceptually driven word retrieval problem or a cognitive-linguistic planning problem, and therefore offer a more language specific measure of production impairment. In our current ongoing experiment, we assessed language production impairment by comparing performance between individuals with PD and matched controls on three language production tasks differing in cognitive demands: 1) a speeded reading task, where participants read aloud as many words on a list as possible in one minute, a relatively simple task that can be performed using grapheme to phoneme conversion, serving as a measure of motor speech; 2) a category fluency task, where participants produced as many words as possible from one semantic category in one minute, serving as a measure of conceptually driven word production with higher executive demands; and 3) a picture description task, where participants described line drawings of people performing actions with no time constrains. Our interest in this last task lies particularly in the pausing patterns (i.e., location, duration and frequency), as this could indicate impairments in conceptually driven word retrieval and/or syntactic planning. Longer and/or more pauses at non-syntactic boundaries will be indicative of lexical retrieval deficits, and at syntactic boundaries will suggest impairment at the syntactic planning level. Moreover, we will correlate results from the picture description task with performance on word reading and category fluency, which will allow to disentangle between motor and executive function impairments, respectively, and language specific deficits. Our findings could give a clearer perspective into the underlying mechanisms that are impaired in individuals with PD. Moreover, it could shed a light into whether including pausing as a linguistic marker in semi-spontaneous speech could contribute to improved diagnosis and treatment in PD.

Topic Areas: Language Production; Disorders: Acquired

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Lexical retrieval in naming and spontaneous discourse in temporal lobe epilepsy

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Introduction: Previous research, that assessed noun and verb production, showed that individuals with temporal lobe epilepsy (TLE) have difficulties with language production at the single word level, whereas spontaneous speech typically remained unattended. The goal of our study was to additionally investigate the lexical characteristics of fluent discourse (lexical diversity) in individuals with left and right TLE as compared to healthy Russian speakers. Methods: 26 individuals with left TLE (17 females, mean age = 29.2, SD = 5.6, mean years of education = 13.7, SD = 2.4), 26 individuals with right TLE (13 females, mean age = 28.5, SD = 5.6, mean years of education = 13.7, SD = 3.3), and 26 healthy Russian speakers (16 females, mean age = 31.5, SD = 9.5, mean years of education = 15, SD = 1.9) were enrolled in the study. During the discourse production task, participants were asked to create a story based on a complex picture representing a situation. Noun and verb production was assessed using object and action naming tests. The data analysis included linear regression modeling with group, education, and clinical parameters as independent factors. Dependent measures were the length and Measure of Lexical Diversity in Text (MLTD) for the discourse and percent of correct answers for the naming tests. Results: As compared to the healthy controls, individuals with left and right TLE showed lower MLTD-values (49.7 in left TLE vs. 65.6 in healthy controls, 56.3 in right TLE vs. 65.6 in healthy controls; adjusted r-squared = 0.09, $p = 0.012$), whereas no difference was observed in the length of the discourse. In both groups of individuals with TLE, performance was also impaired on object (87.5% in left TLE vs. 97.6% in healthy controls, 91.6% in right TLE vs. 97.6% in healthy controls; adjusted r-squared = 0.27, $p < 0.001$) and action (90.4% in left TLE vs. 97.8% in healthy controls, 92.7% in right TLE vs. 97.8% in healthy controls; adjusted r-squared = 0.18, $p < 0.001$) naming. No differences were observed between the individuals with left and right TLE in any of the tasks. Conclusion: Our naming tests results are in line with previous studies demonstrating impaired single word production in individuals with left and right TLE. In addition, we observed decreased lexical diversity in spontaneous discourse, irrespective of the lateralization of the epileptogenic focus. We suggest that the reduced performance on both language levels reflects difficulties with lexical retrieval and/or reduced vocabulary size.

Topic Areas: Language Production; Disorders: Acquired

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Asynchronous Behavioral and Neurophysiological Changes in Word Production in the Adult Lifespan

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While performance in most cognitive domains (episodic memory, working memory, attention and inhibitory control, general processing speed, etc.) start declining in early adulthood (e.g. Salthouse, 2004) language capacities only decline beyond the age of 60-70 years-old (e.g. Salthouse, 2010). Behavioral changes in language tasks between young and older adults are accompanied by changes in neurophysiological brain activity. In referential word production tasks (picture naming), Valente & Laganaro (2015), reported ERP brain activations divergences between young and older adults in a specific time-window, between 150 and 250 ms after the picture onset. This time period is associated with lexical-semantic processes and suggested that word production modifications in aging could be influenced by the age-related changes affecting the semantic system and its processing. However, most neuroimaging studies on aging of language skills compared only extremes of the adulthood (20-30 years-old and older than 70). It is therefore unclear when the observed neurophysiological changes start in the adult lifespan and whether they only arise in older adults. In this study we aimed to investigate the electrophysiological (EEG) and event-related (ERP) patterns underlying word production in a picture naming task across the adult lifespan, i.e. by including intermediate age-groups between young adults and elderly, thus filling the gap between the two extremities of the adult lifespan. High-density EEG was recorded in 95 French native speakers aged 16 to 80 years-old divided into five age-groups named: “adolescents”, “young adults”, “adults”, “young-old adults” and “older adults”. Behavioral results showed that only the “older adults” group (70-80 years-old) displayed slower production latencies relative to the “young adults” group (20-30 years-old). However, significant neurophysiological changes are already observed starting from the age of 40. Microstates analyses showed a specific pattern in all age-groups over 40 years, but not in the two youngest groups. This specific pattern was observed in the time window between 150 and 220 milliseconds after the image onset, likely associated with lexical-semantic processes and its presence progressively increased in the three older adult groups. Source localization in this specific time-window, highlighted with aging a shift from temporo-occipital to more frontal activation and an activation of a more temporo-parietal extended network. The present findings indicate that neurophysiological changes related to word production appear from the age of 40 year-old, i.e. long before behavioral decline. The time window and source localization of such progressive changes are compatible with an enrichment/reorganization of the lexical-semantic network throughout the lifespan. This observation is in line with the hypothesis of the “semanticization of cognition”, which predicts a maintenance or a growth of semantic abilities over the lifespan and a decline in cognitive control resources with age (Spreng & Turner, 2019). This mechanism would allow the maintenance of language skills longer than for other cognitive functions. These results lead to consider that studying language processes using mostly undergraduate young adults (20-30 years-old), may not be representative to study “adulthood”.

Topic Areas: Language Production; Meaning: Lexical Semantics

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Anomia rehabilitation in drug-resistant left temporal lobe epileptic patients using a single case Experimental Design (SCED)

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Introduction: Around 40% of patients who undergo a left temporal lobe epilepsy (LTLE) surgery suffer from anomia (i.e., word-finding difficulties), a condition that negatively impacts quality of life (Miller et al., 2019). Word finding difficulties could result from perturbations of the semantic or the phonological systems (Miozzo et Hamberger, 2015 ; Campo et al., 2014). These two cognitive loci have been linked to the functional organization of the temporal lobe (Hamberger et al., 2016; Miozzo et al., 2016). Despite these observations, cognitive rehabilitation programs are still understudied in this population. The available literature reports some rehabilitation programs for verbal memory or attention (Farina et al., 2015; Joplin et al., 2018) whereas language rehabilitation has been poorly and rarely described (Mazur et al., 2015). Method: We used a Single Case Experimental Design (SCED; Krasny-Pacini et Evans, 2018 ; Perdices et al., 2019) to assess the effect of an intensive speech therapy rehabilitation in 4 drug-resistant temporal lobe epilepsy patients. The anomia rehabilitation protocol we developed was based on cognitive descriptions of the word finding deficit in temporal lobe epilepsy, clinical research regarding success factors in anomia rehabilitation in cerebro-vascular aphasia (Jacquemot et al., 2012), and consideration of other psychological features such as stress (Neumann, 2018). We enforced a double rehabilitation strategy, combining both semantic and phonological intensive training with a psycho-education approach to help patients coping with their daily communication issues. We repeatedly assessed word finding abilities for trained and untrained words, before and during the therapy using a multiple baseline design. Three patients entered concurrently in the hospital protocol while the fourth patient benefited from a later self-rehabilitation protocol, inspired by the previous ones and supervised by a private speech therapist. Results: All patients completed the rehabilitation procedure successfully. Visual and statistical analysis converged on a positive effect of the intervention on naming skills. Patients improved specifically for trained words but also for untrained words during the therapy, suggesting some generalization effects. However, the rehabilitation did not have clear positive effects on naming speed. The patient who benefited from self-rehabilitation responded similarly as the first three patients despite a different context and manner of intervention. Discussion: These left temporal lobe epilepsy patients benefited from an intensive targeted anomia rehabilitation protocol. Nevertheless, we found no relation between naming improvement and changes in anomia complaint. A negative impact of seizures was suspected because of a brief decrease of naming performance following the crisis. In patient 4, the procedure was adapted as a self-rehabilitation procedure that showed similar positive effects. These results open promising avenues for helping epileptic patients suffering from anomia. References : Campo et al., 2016, Brain Structure and Function, https://doi.org/10.1007/s00429-014-0919-1; Farina et al., 2015, Epilepsy research, https://doi.org/10.1016/j.eplepsyres.2014.10.017; Joplin et al., 2018, Neuropsychology review, https://doi.org/10.1007/s11065-018-9367-7; Hamberger et al., 2016, Epilepsy&Behavior, https://doi.org/10.1016/j.yebeh.2016.04.021; Mazur et al., 2015, Epilepsia, https://doi.org/10.1111/epi.12963; Miller et al., 2019, Epilepsy&Behavior, https://doi.org/10.1016/j.yebeh.2019.106484; Miozzo et Hamberger, 2015, Neuropsychology, https://doi.org/10.1037/neu0000097; Miozzo et al., 2017, Human brain mapping, https://onlinelibrary.wiley.com/doi/epdf/10.1002/hbm.23409; Neumann, 2018, Clinical Linguistics&phonetics, https://doi.org/10.1080/02699206.2017.1326166; Perdices et al., 2019, Behavior Modification, https://doi.org/10.1177/0145445519863035.

Topic Areas: Language Therapy; Language Production

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Changes in Effective Connectivity Following Language Treatment for post-stroke patients with Aphasia

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//Background// In recent years, many studies focused on the mechanisms underlying language rehabilitation after left hemisphere stroke. Some studies suggest that normalization of the language network, is crucial for language recovery, while others suggest that compensatory processes, such as right hemisphere involvement in language processing, support language recovery. We aimed to examine changes in brain connectivity during language therapy, which can shed new light on this question. Our second aim was to examine to what extent treatment-related changes in brain connectivity are specific to the treated linguistic process (i.e., phonology), or whether they generalize to other neurolinguistics processes (i.e., semantics). //Methods// This is a reanalysis of reported data (Leonard et al., 2015; Leonard, Rochon, & Laird, 2008; Rochon et al., 2010). Four participants with aphasia (PWA) and anomia following left hemisphere stroke and eight healthy controls (HC) participated in the study. Two fMRI scans were administered for all participants with a 3.5-month interval on average. In the time between the two fMRI scans, PWA underwent phonological component analysis treatment (PCA). The fMRI scans included phonological and semantic tasks and a perceptual matching control task. //Analysis// Dynamic Causal Modelling (DCM) was used to examine effective connectivity among three right hemisphere regions: dorsal IFG (rdIFG), ventral IFG (rvIFG), and lateral temporal cortex (rLTC). The analysis was conducted separately for the phonological and semantic tasks, and all possible intrinsic and extrinsic connections were included in the model. We identified connections averaged across the linguistic and perceptual condition in each task (A matrix) and connections that were modulated only by the language (phonological or semantic) task (B matrix). For these connections, we asked which changed from pre- to post-treatment in PWA but not in HC. //Results// 1) The averaged connectivity across conditions (A matrix), changed in three connections from pre- to post-treatment only in PWA: bidirectional rvIFG↔rLTC in the phonological task, and self-connection of rLTC in the semantic task, all increasing in resemblance to HC. Because these conditions reflect common lexical access components, which are typically associated with a bilateral network, the increased resemblance to HC may reflect normalization of connectivity in the intact RH. 2) The modulatory effect of the phonological condition (B matrix) on the connection rLTC → rdIFG was strengthened during treatment only in PWA, unlike HC in whom this effect is inhibitory. Because phonological processing is typically associated with the left hemisphere, this change may reflect compensation. No changes were found in the effect of the semantic condition. //Conclusions // Following language treatment, we found changes in the connectivity among RH homologs to language regions in PWA. The results indicate that both compensatory and normalization processes play a role in language recovery, and both may simultaneously underlie the involvement of the RH in the chronic phase of aphasia. Most treatment-related changes in the current study were associated with phonological processing, which was the focus of treatment, with an indication of changes in connectivity associated with semantic processing. Nevertheless, the small sample size used in the current study limits its generalization.

Topic Areas: Language Therapy; Methods

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Attention to attention in aphasia – elucidating effects of task and modality

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It is increasingly acknowledged that patients with aphasia following a left-hemisphere stroke often have difficulties in other cognitive domains. One of these domains is attention, the very fundamental ability to detect, select, and react to the abundance of stimuli present in the environment. Simple and more complex attentional functions are usually distinguished, and a variety of tests has been developed to assess attentional performance on a behavioural level by collecting quantitative (reaction times, variability) and qualitative (omission or commission errors) measures. Attentional performance in aphasia has been investigated previously, but often only one specific task, stimulus modality, or type of measure was considered and usually only group-level analyses or data based on experimental tasks were presented. We report detailed analyses on a rich dataset including patients' performance on various subtests of two well-known, standardised neuropsychological test batteries assessing attention. We aimed at elucidating aspects of attentional performance in patients with chronic post stroke aphasia, in particular: 1) how many patients show impaired performance in comparison to normative data, in which tasks and on what measure; 2) how the different tasks and measures relate to each other and to patients' language abilities; 3) whether there are differences between modalities of stimulus presentation (auditory versus visual). Up to 32 patients with varying aphasia severity were assessed with subtests from the Test of Attentional Performance (TAP) as well as the Test of Everyday Attention (TEA). Depending on the task and measure, between 3 and 54 percent of the patients showed an impaired performance level compared to normative data. The highest proportion of impaired performance (quantitative and qualitative) was noted for complex attention tasks involving auditory stimuli. Patients differed in their patterns of performance and only the performance in the divided attention test was (weakly) associated with their overall language impairment. We thus extend previous research in characterizing different aspects of attentional performance within one sample of patients with chronic post stroke aphasia. Performance in a broad range of attention tasks and measures was variable and largely independent of patients' language abilities, which underlines the importance of assessing this cognitive domain in patients with left-hemisphere lesions. Notably, a considerable proportion of patients showed difficulties with attention allocation to auditory stimuli. The reasons for these potentially modality-specific difficulties are currently not well understood and warrant additional investigations, also to further elucidate the observed association with patients' language impairments.

Topic Areas: Disorders: Acquired; Control, Selection, and Executive Processes

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Damage to Broca's area does not contribute to long-term speech production outcome after stroke

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Broca's area in the posterior half of the left inferior frontal gyrus has long been thought to be critical for speech production. The current view is that long-term speech production outcome in patients with damage in and around Broca's area is best explained by the combination of damage to Broca's area and neighbouring brain regions including the underlying white matter, which was affected in Paul Broca's two historic cases. Here, we dissociate the effect of damage to Broca's area from the effect of damage to neighbouring brain regions by studying long-term speech production outcome in 134 stroke survivors with relatively circumscribed left frontal lobe lesions that spared posterior speech production areas in lateral inferior parietal and superior temporal association cortices. Collectively, these patients sustained varying degrees of damage to one or more of nine atlas-based grey or white matter regions: Brodmann areas 44 and 45 (together known as Broca's area), ventral premotor cortex, primary motor cortex, insula, putamen, the anterior segment of the arcuate fasciculus, uncinate fasciculus and frontal aslant tract. Spoken picture description scores from the Comprehensive Aphasia Test were used as the outcome measure. Multiple regression analyses allowed us to tease apart the contribution of other variables influencing speech production abilities such as total lesion volume and time post-stroke. We found that, in our sample of patients with left frontal damage, persistent speech production impairments were solely predicted by the degree of damage to the white matter, directly above the insula, in the vicinity of the anterior part of the arcuate fasciculus, with no contribution from the degree of damage to Broca's area (as confirmed with Bayesian statistics). The effect of white matter damage cannot be explained by a disconnection of Broca's area, because the speech production abilities of patients with direct damage to Broca's area and relative sparing of the white matter in the vicinity of the anterior part of the arcuate fasciculus were, on average, within the normal range and significantly better than those of patients with damage to the white matter in the vicinity of the anterior part of the arcuate fasciculus and relative sparing of Broca's area. Our findings therefore provide evidence for three novel conclusions: (i) Broca's area damage does not contribute to long-term speech production outcome, irrespective of the extent of the stroke lesion; (ii) persistent speech production impairments after white matter damage in the vicinity of the anterior part of the arcuate fasciculus cannot be explained by a disconnection of Broca's area; and (iii) the prior association between persistent speech production impairments and Broca's area damage can be explained by co-occurring white matter damage, above the insula, in the vicinity of the anterior part of the arcuate fasciculus.

Topic Areas: Disorders: Acquired; Language Production

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The Role of Virtual Communication on Well-Being in People with Aphasia and Elderly Control Participants

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Background: The risk of stroke increases exponentially with age, meaning older adults must overcome stroke and age-related declines that threaten their social participation and psychological well-being. However, with Covid-19 accelerating society's reliance on technology, there is an increased need for virtual communication (VC), intensifying the challenges faced by vulnerable populations such as older adults and people with post-stroke aphasia (PWA). Aims: To investigate the role of VC on well-being in PWA and older adult controls and to determine how Covid-19 restrictions have impacted both groups' VC. Methods: A between groups correlational design was employed. Seven PWA (M=68.29 years, SD=8.81) and forty-two controls (M=72.07 years, SD=5.18) completed an online questionnaire including The Burden of Stroke Communication Difficulty Scale, a newly developed Virtual Communication Scale and The Warwick-Edinburgh Mental Well-Being Scale. Results: Aphasia severity negatively correlated with VC, while VC positively correlated with PWA's well-being. For controls, only age and VC negatively correlated. PWA had significantly lower VC and well-being scores than controls, but neither group reduced their VC during Covid-19 restrictions, despite lockdown limiting access to regular technological support from others outside the household. Thematic analyses explained this with two main themes entitled 'relationships' and 'reluctance'. Discussion: Aphasia negatively impacts VC and well-being beyond the consequences of ageing, and with VC positively influencing PWA's well-being, virtual communicative training could be beneficial. In future replications, research should consider how technological ability and attitudes impact the relationship between VC and well-being for both groups.

Topic Areas: Disorders: Acquired; Language Therapy

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Lesion Correlates of Auditory Sentence Comprehension Deficits in Post-Stroke Aphasia

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Auditory sentence comprehension requires coordination of multiple levels of processing: auditory-phonological, lexical-semantic comprehension, syntactic and discourse processing, as well as executive functions such as verbal working memory (WM) and cognitive control. The phonological and lexical aspects appear to be supported by a “ventral stream” of regions in the lateral temporal lobe (e.g., Hickok & Poeppel, 2007), but the critical regions are less clear at the sentence level. Left inferior frontal cortex, inferior parietal cortex superior, and posterior superior temporal cortex are the most consistently implicated regions for sentence-level comprehension deficits (for a review see Wilson, 2017). Most prior studies on this topic have either used composite measures of comprehension or specifically focused on syntactically complex (or non-canonical) sentence structures. In the present study, sentence comprehension was measured using the Token Test (De Renzi & Vignolo, 1962), which does not require complex syntactic or semantic processing, but it does require combinatorial processing, sequencing, verbal WM, and possibly semantic control (repetition of items from semantic categories tends to produce competition that requires control resources to resolve, as seen in blocked cyclic naming and in “access” deficits more generally; e.g., (Mirman & Britt, 2014)). Prospectively collected MRI and psycholinguistic data from 50 participants with aphasia secondary to a single left hemisphere stroke were analysed (see also Thye et al., 2021). Lesion-symptom mapping (LSM) analyses were conducted in R (version 3.5.1) using the LESYMAP package (version 0.0.0.9220). All analyses only considered voxels with at least 10% (n=5) lesion involvement and were corrected for overall lesion size. Mass-univariate analyses were also corrected for multiple comparisons using continuous permutation-based FWER with $p<0.05$ of observing more than v=100 false positive voxels (Mirman et al., 2018). Multivariate LSM was conducted using SCCAN with 4-fold cross-validation to optimise sparseness (Pustina et al., 2018). The mass-univariate VLSM identified 4,142 suprathreshold voxels, primarily in the posterior superior temporal lobe (STG, MTG, and Heschl’s gyrus) and a smaller cluster in IFG pars triangularis. Multivariate SCCAN LSM also identified a relatively sparse solution (optimal sparseness = 0.173, CV correlation = 0.55, $p<0.0001$) with suprathreshold voxels in posterior superior temporal cortex, IFG pars triangularis, and frontal white matter (superior and anterior corona radiata). These results converge with prior work that identified posterior superior temporal and inferior frontal regions as critical for sentence comprehension. We did not observe involvement of anterior temporal regions, perhaps because the semantic demands were quite limited. Nor did we observe involvement of inferior parietal regions, perhaps because the demands for hierarchical syntactic processing were limited (Matchin & Hickok, 2020). Rather, the critical regions are ones associated with speech perception, verbal WM, and semantic control, suggesting that these are the primary drivers of Token Test performance. The Token Test is also used in clinical contexts, so in addition to providing further insight into the neural correlates of sentence comprehension deficits, these results are relevant for interpreting Token Test results in clinical settings.

Topic Areas: Disorders: Acquired; Methods

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A comparison of observed and simulated disconnection measures in chronic post-stroke aphasia.

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There is a long-standing history of mapping behavioural deficits to brain damage in stroke patients (i.e., inferior frontal regions for speech production and posterior temporal regions for speech comprehension). Research studies typically focus on grey matter but we know that white matter (dis-)connections are important (Catani et al., 2005). In practice, collecting diffusion weighted/tensor imaging (DWI/DTI) data in vulnerable populations is challenging as: a) they not essential for clinical assessment; b) they require expert analytics and c) are time consuming/expensive. This has led to multiple algorithms being developed to infer disconnections given a particular lesion profile. A number of studies within the stroke literature have utilised inferred disconnections to build prediction/prognostic models (e.g. Pustina et al., 2018; Hope et al., 2018) but have had mixed outcomes. In particular, a recent study has compared predictions using lesion location with inferred structural and functional disconnections (Salvalaggio et al., 2020). Inferred disconnections are typically obtained using the lesion location (as a seed) in healthy younger adults, which assumes that: a) changes due to normal aging are negligible; and b) spared regions in stroke patients are ‘healthy’ (specifically the contralateral hemisphere). To date, there has been no formal comparison of the observed disconnections in-vivo with a range of inferred disconnections; therefore, this study set out to address this question. In addition, we also used lesion location and each disconnection method as features in a 5-fold cross validation prediction analysis. We obtained in-vivo diffusion data using the same sequence parameters from left-sided chronic-stroke patients (N=77), age and education matched controls (N=22), and younger controls (N=20). We also included high resolution DWI data from the Human Connectome Project (HCP, N=37). Disconnection maps were estimated in eight ways: in-vivo stroke patients against 1) matched controls; 2) young controls; 3) HCP controls; and pseudo-lesion inferred disconnections (i.e. insert lesion into healthy data and remove intersecting connections) in 4) matched controls; 5) young controls; and 6) HCP controls. We also used two popular methods to obtain disconnection maps using the: 7) Brain Connectivity and Behaviour toolkit (BCB; Foulon et al., 2018) and 8) Network Modification tool (NeMo; Kuceyeski et al., 2013). Methods 2-8 were compared with Method 1 (the target) in two ways. First, we used correlation and cosine similarity of the disconnection values (summarised using AAL atlas). Second, we used permutation testing to determine if each Method differed to the target for each subject (quantifying the proportion of dissimilar subjects per method). The first analysis showed that every method was significantly different to the target, with the young controls being the closest. The second analyses showed that the proportion of dissimilar subjects were confined to the right hemisphere (6.5-54.5%), whereas the left hemisphere fared better (0-6.5%). Finally, we found no evidence of improved prediction performance using any disconnection method after accounting for lesion location. In summary, the results showed that inferred disconnection methods do not adequately reflect in-vivo disconnections; however, disconnection measures (from any method) did not account for unique variance in prediction analyses.

Topic Areas: Disorders: Acquired; Methods

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Processing of degraded vocal signals in primary progressive aphasia and Alzheimer's disease

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The ability to understand speech and paralinguistic signals is crucial for everyday communication, yet generally we are required to process such signals under suboptimal listening conditions, such as background noise. This presents the auditory brain with an intensely demanding computational problem, which it normally solves automatically and efficiently. However, the processing of degraded speech and other vocal signals is potentially vulnerable to neurodegenerative diseases that target the distributed neural circuits mediating vocal signal decoding. Here we addressed this issue in a cohort of patients representing all major variant syndrome of primary progressive aphasia (PPA), in relation to patients with Alzheimer's disease (AD) and healthy age-matched controls. We used noise-vocoding to reduce the amount of spectral information in vocal signals: in two separate experiments, we assessed the impact of this manipulation on the recognition of spoken words and emotional prosody (three-digit numbers spoken in one of the three universal emotions), respectively. The nonfluent and logopenic PPA and AD groups showed a raised threshold (channel number) for recognition of vocoded spoken words relative to healthy controls. All dementia syndromic groups showed reduced recognition of emotional prosody after vocoding compared with natural speech, however this perceptual 'cost' was most pronounced in the logopenic PPA group and least marked in the nonfluent PPA group. Our findings suggest that processing of degraded vocal signals may differentiate dementia syndromes based on distinct pathophysiological mechanisms.

Topic Areas: Disorders: Acquired; Perception: Auditory

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Electrophysiological correlates of spoken and sung word processing in chronic aphasia and healthy aging

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Speech production impairment is a hallmark of stroke-induced aphasia. Singing, on the other hand, is often less affected. Stroke in the left perisylvian language area may also compromise spoken word comprehension, by disruption of the word memory circuits. Whether this is reflected in the neural processing of spoken words in chronic aphasia and in old age in general, is poorly understood. We presented disyllabic spoken and pitch-modulated words and pseudowords, carefully matched in their phonological and other acoustic properties, to patients with chronic aphasia and age-matched healthy elderly control participants. The fundamental frequency modulation of the first syllables mimicked sung input. EEG was recorded in a passive listening condition, where the focus of attention was directed on watching a silent movie in order to reduce effects related to task and attentional demands. ERPs for the first syllable were extracted in order to assess the impact of F0-modulation to obligatory responses for speech sounds. Further, ERPs time-locked to the second syllable, which importantly disambiguated the lexical from the meaningless items, were analysed to probe lexical activation in the two modalities and between the groups. The P1-N1 complex for the pitch-modulated syllable showed a clear effect of modality, with sung input producing larger amplitudes, indicating stronger neural suppression for the spoken items with homogeneous F0 in comparison to the sung syllables. Furthermore, controls elicited stronger frontocentrally prominent P1 compared to the patients with chronic aphasia. N1 amplitudes did not differ between the groups but the spoken items were generally stronger in the parietal sites. The P2 response showed partially differing dynamics to the P1-N1, with spoken syllables eliciting stronger frontocentral response than the sung ones, possibly indicating better neural discrimination and auditory encoding of the spoken syllables. Similar to the P1, the P2 was larger in the control compared to the aphasia group across modalities, referring to impaired speech sound encoding in aphasia. For the second syllables, the P1 was larger to sung compared to spoken items across groups. This effect was reversed in the N1, which was stronger for the spoken compared to sung items across groups. However, overall N1 was stronger in controls. The effect of greater amplitudes to spoken compared to sung input persisted at the N250 and N400 latencies. Interestingly, controls showed the expected N250 and N400 enhancement for spoken pseudowords over real words but no such difference was observed for the sung items. In contrast, the N250 was larger for pseudowords than real words only in the sung domain in aphasics, but this effect was reduced in the N400. These results indicate impaired automatic spoken word memory trace activation in chronic aphasia, but introducing pitch modulation in the speech prosody akin to singing seems to facilitate lexical access. Hence, using singing as a means for communication in chronic aphasia may have beneficial effects for comprehension and strengthening of lexical memory traces.

Topic Areas: Disorders: Acquired; Speech Perception

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Quantitative MRI reveals differences in subcortical microstructure in children with DLD

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Children with developmental language disorder (DLD) struggle to learn their native language for no obvious reason. DLD is a common neurodevelopmental disorder (prevalence ~7%). DLD increases risk for academic underachievement, unemployment, and social and behavioural difficulties. Although we know that DLD does not result from gross neural lesions, we do not have a clear picture of how brain anatomy differs in children with DLD. We previously hypothesised that the dorsal striatum is important for language learning, and may be abnormal in children with DLD (Krishnan, Watkins, & Bishop, 2016). However, empirical evidence supporting this view has been mixed. Factors contributing to the inconsistency of findings across studies include small sample sizes, heterogeneity of groups studied, as well as the scanning methodology used. Here, we report new findings using a robust and cutting-edge quantitative imaging protocol – multiparameter mapping (MPM) – which sheds new light on microstructural neural differences in children with DLD. When using standard structural imaging protocols, e.g., T1-weighted scans, the contrast between grey and white matter reflects a combination of histological properties such as iron content, myelin, cell density and water. Recently, quantitative MRI methods have been used to map specific indices of tissue microstructure, myelination, and macromolecular content, and the resulting maps are highly reproducible across individuals and scanners. For instance, using the MPM semi-quantitative imaging protocol (Weiskopf et al., 2013), multiple maps can be constructed to probe different tissue properties. The generated maps index: 1) the longitudinal relaxation rate R1 (1/T1); 2) the transverse relaxation rate R2* (1/T2*); and 3) Magnetization Transfer Saturation (MTsat). The dominant influence on R1 in cortical tissue is myelin (Lutti et al., 2014), although R1 indexes both myelin and iron in subcortical areas. R2* is sensitive to iron concentration, especially in ferritin-rich regions, such as the basal ganglia, and MTsat indexes myelin through myelin's interaction with water molecules. The MPM protocol therefore represents an unparalleled means of acquiring time-efficient, multi-modal, whole-brain data with insight into tissue composition. MPM data were collected as part of the Oxford BOLD study (Krishnan et al., 2021). After quality control, we retained data from 56 typically-developing (TD) children and 34 children with DLD. Children with DLD showed lower MTsat values relative to TD children in the left ventral sensorimotor cortex, left Heschl's gyrus, superior temporal gyrus and caudate nucleus bilaterally. Children with DLD also had lower R1 values across a widespread network of motor, premotor, and temporal cortex, as well as in the caudate nuclei bilaterally. Differences in MTsat and R1 survived whole-brain correction using threshold-free cluster enhancement ($P<.05$ FWE), and showed overlap in left ventral sensorimotor cortex, superior temporal gyrus and the caudate nucleus bilaterally. No group differences were noted in R2* maps. A voxel-based morphometric analysis of T1w-scans did not reveal any differences, indicating the greater sensitivity to microstructural differences afforded by the use of MPM. These empirical findings strongly support our hypothesis, indicating there are atypical amounts of grey matter myelin in the dorsal striatum and language-relevant cortex in DLD.

Topic Areas: Disorders: Developmental; Methods

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When dogs make meow: an electrophysiological exploration of onomatopoeia processing in toddlers

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The goal of this study was to investigate cross-modal lexical-semantic processing at different stages of language development. Adults often communicate with children by using infant-directed speech that typically involves speech prosody, lexical and syntactic modifications (Soderstrom, 2007). The lexical modifications frequently include Onomatopoeia, which phonetically imitates sounds or suggests the source of described sounds. Researchers found that Onomatopoeias are very common in 8- to 16-month-old infant's production repertoire and that they usually decrease in terms of relative proportions between 16 and 20 months of age, along with an increase of other word categories, including common nouns (Camaioni and Longobardi, 1995). In this work, we investigated whether different types of lexical information carrying the same meaning (Onomatopoeias, Common nouns) engage similar or different semantic processing and whether they change with increasing age. In addition, we analyzed how different types of lexical information are tied to the object they refer to and whether cross-modal semantic processing is affected by the type of lexical information. We recorded event-related potentials to onomatopoeic utterances and common nouns associated with pictures of familiar objects in children from two age groups: 16 to 20 months and 24 to 30 months (n = 20, respectively). In addition, we included an adult comparison group. Brain activity was measured during the presentation of the four conditions: in the congruent Common Noun condition, the auditory word matched the content of the image; in the Incongruent Common noun condition, the auditory word did not match the image; in the Congruent Onomatopoeia condition, an onomatopoeia word matched the image; in Incongruent Onomatopoeia condition the onomatopoeia did not match the image. The younger group of children revealed a greater posterior N400 to incongruent onomatopoeic words than to congruent ones. No N400 differences were observed in response to common nouns. This result suggests that the onomatopoeic utterance was more strongly associated to the meaning of the object at an earlier stage of language development. The older group of children showed a greater N400 to incongruent common nouns compared to congruent ones and no difference in the N400 between congruent and incongruent onomatopoeic words. This result was in line with previous studies that revealed that at this stage children associate pictures of known objects with their correct name (Friedrich and Friederici, 1998) and replace the onomatopoeic utterance with the common noun associated with the meaning of a given object. Furthermore, adults revealed an N400 to both incongruent onomatopoeic words and common nouns, showing that they were able to process both the two lexical forms associated with the representation of a visual object. Overall, our results revealed different N400 effects for onomatopoeic utterances and common nouns across the different age groups. This suggests that these categories are differently organized in children's semantic memory and that the acquisition of linguistic abilities affects and modifies semantic processing of different lexical information.

Topic Areas: Meaning: Lexical Semantics; Development

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Studying the anatomical basis of language lateralisation using white matter connectometry

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Introduction: In approximately 90% of the general population language depends on specialised brain networks in the left cerebral hemisphere. Some people have “atypical” language representation (right hemisphere or bilateral lateralisation), which is more prevalent in left-handers (Mazoyer et al, 2014). The reasons for this hemispheric specialisation are unknown. It has been suggested that brain structural asymmetry is related to functional language lateralisation. Studies using structural magnetic resonance imaging (MRI) investigations have reported a leftward asymmetry of language relevant brain regions, including the inferior frontal gyrus, superior temporal gyrus, and interconnecting white matter tracts such as the arcuate fasciculus (Catani et al, 2007; Barrick et al, 2005; Keller et al, 2007). However, few studies have used whole-brain diffusion MRI approaches to investigate how white matter architecture is related to functional language lateralisation in healthy people. In the present study, we mapped the relationship between whole-brain white matter fibre quantitative anisotropy (QA) and functional MRI determined language lateralisation in a large cohort of healthy people. Methods: We investigated 188 healthy young (22-35 years) adult participants from the Human Connectome Project (HCP) database. All participants underwent diffusion and functional MRI. The functional MRI language task used was developed by Binder and colleagues (2011) and consists of two runs that each interleave four blocks of a story task and four blocks of a math task. Functional activation associated with language comprehension was determined using a story-math contrast. Hemispheric language comprehension lateralisation was determined using a laterality index (LI) for each participant’s activated regions ($Z > 1.96$, corresponding to two-tailed uncorrected $P < 0.05$). The relationship between quantitative anisotropy (QA) and a continuous measure of LI was assessed using a DSI Studio Connectometry analysis, which was based on a deterministic fibre tracking algorithm and uses QA as the termination index (Yeh et al, 2016). Results: Based on LIs, participants were classified as left (119), right (11), and bilateral (58) lateralised individuals. Both left-hemisphere dominant and atypically-lateralized individuals showed activations in classical language areas: Broca’s area, Wernicke’s area, angular gyrus, posterior cingulate cortex, and lateral prefrontal cortex. Across groups, LIs were significantly ($FDR < 0.05$) positively correlated with QA in the forceps minor, left inferior fronto-occipital fasciculus, left uncinate fasciculus, and the cingulum bilaterally. The QA of the right fornix and right uncinate fasciculus was negatively correlated with LIs. Conclusion: This is the first white matter connectometry study of language lateralisation in healthy individuals. Using this novel connnectometry approach based on correlational tractography paradigm we report that language lateralisation is associated with white matter QA – a potential marker of connectivity strength – in anterior commissural regions and focal regions of long association fibres.

Topic Areas: Development; Computational Approaches

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Predictive speech processing evolves across the adult lifespan

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Whereas healthy-aging older adults generally have preserved speech comprehension [1], they seem to use context information less efficiently than younger adults [2]. The N400 component, an event-related potential (ERP) related to sentence-level meaning and sensitive to context integration and how predictable words are, is consistently smaller in amplitude and delayed in older adults [2,3]. In a more ecologically valid experiment where participants listened to a naturally spoken story, researchers [4] found delayed peaks in older adults when investigating the relationship between the measured EEG and a speech model containing information about how surprising or unexpected a word is in its linguistic context, i.e. word surprisal (see [5]). However, this study did not control for acoustic and speech segmentation-related activity, hence responses were not specific to top-down predictive speech processing but also included bottom-up acoustic aspects [6]. To clarify the effect of age specifically on predictive speech processing, we explored the unique contribution of prediction-related speech features (while controlling for bottom-up processing) across the adult life span. Fifty-two participants between 17 and 82 years of age listened to a 14-minutes-long story while 64-channel EEG was recorded (dataset recorded for [7]). Several speech features were derived from the stimulus and combined into 2 models for further analysis, i.e. (1) combining spectrogram, acoustic edges, phoneme onsets and word onsets and (2) containing these identical features plus predictive coding features such as phoneme surprisal, cohort entropy and word surprisal (for details see [6]). The delay between EEG data and the 2 feature combinations was modeled over time (integration window: 0-600ms), i.e. the temporal response function (TRF), and peak latencies were extracted. The TRF was further used for training and predicting estimated EEG responses to unseen story parts, which in turn were correlated with the original EEG data, referred to as prediction accuracy hereafter. To isolate the unique contribution of predictive speech processing, the prediction accuracies of model 1 were subtracted from model 2. Participant age and prediction accuracies of the unique contribution of predictive speech processing features were significantly correlated when all electrodes were averaged (model: $R2adj=.1061$, $F(1,50)=7.054$, $p=.0106$; age effect: $\beta=-2.962e-05$, $t=-2.656$, $p=.0106$). Regional analyses in which bilateral electrodes were grouped in frontal, temporal and centro-parietal electrode locations demonstrated that the correlation with age was only significant in the centro-parietal region (model: $R2adj=.2023$, $F(1,50)=13.93$, $p=.0004$; age effect: $\beta=-6.027e-05$, $t=-3.733$, $p=.0004$). The more advanced the age of the participants was, the lower the prediction accuracies were. Furthermore, the TRF peak latencies were significantly longer in older participants for cohort entropy (model: $R2adj=0.06512$, $F(1,48)=4.413$, $p=.04094$; age effect: $\beta=0.09836$, $t=2.101$, $p=.04094$) and word surprisal (model: $R2adj=0.1013$, $F(1,48)=6.521$, $p=.01389$; age effect: $\beta=0.12271$, $t=2.554$, $p=.01389$), but not for phoneme surprisal. These results converge with the N400 ERP literature and demonstrate aging effects in predictive speech processing, even when acoustic and speech segmentation-related effects are controlled for. Using natural speech to investigate predictive speech processing can provide a valuable tool for understanding the shift in speech processing dynamics across the adult lifespan and more specifically, in older age.

Topic Areas: Development; Meaning: Combinatorial Semantics

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Infants Show Increased Neural Tracking of Intonation during Natural Infant-Directed Speech

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Infants are social individuals and engage in interactions long before they can speak (Bell, 1974). When interacting with infants, adults use a characteristic register, termed infant-directed speech (IDS) (Soderstrom, 2007). Infants prefer IDS over adult-directed speech (ADS) (Cooper & Aslin, 1990); moreover, IDS assists infants' word segmentation and recognition (Schreiner & Mani, 2017; Singh et al., 2009). This IDS benefit has been argued to reflect enhanced amplitude modulations at the frequency of intonation (< 3 Hz; Leong et al., 2017), which is critical for word segmentation (Goswami, 2019). While IDS is known to benefit the electrophysiological tracking of speech by infants (Kalashnikova et al., 2018), it remains unclear whether this results specifically from intonation or other factors, such as the syllabic rhythm. To test this, we compared infants' tracking of IDS and ADS at both the intonation rate (1–3 Hz) and the syllable rate (3.3–8.3 Hz). In parent-infant dyads (n = 30), parents described novel objects to their 9-month-olds while infants' EEG was recorded. For IDS, parents were instructed to talk to infants as they would typically do, while for ADS, parents were supposed to describe the objects to an adult. Acoustic modulations were enhanced in IDS (all $p < .005$). Cortical tracking of speech was assessed by speech–brain coherence, which measures the synchronization between the EEG and the speech envelope. Higher synchronization between neural activity and speech supports speech processing (for review, see Meyer, 2018). We expected higher speech–brain coherence at the syllabic and intonation rates for IDS compared to ADS, indicating increased neural tracking of slow amplitude modulations. Our analyses revealed significant speech–brain coherence at both syllabic and intonation rates (both $p < 0.001$), indicating that infants track speech during natural interactions. In addition, we found significantly higher speech–brain coherence for IDS as compared to ADS at the intonation rate ($p = .01$), but not the syllabic rate ($p = .31$)—indicating that the IDS benefit arises primarily from enhanced intonation. Thus, neural tracking is sensitive to parents' speech adaptations during natural interactions, probably facilitating higher-level inferential processes such as word segmentation. This makes neural tracking a potential neural mechanism for infants' word segmentation from continuous speech.

Topic Areas: Development; Perception: Auditory

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The trajectory of speech perception development: Investigating event-related potential Mismatch Responses to different speech and non-speech features in infants of 2, 6 and 10 months

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Infants rapidly advance in their speech perception, reflected in the transition from an immature, positive-going to an adult-like, negative-going electrophysiological mismatch response (MMR) in auditory deviancy detection. Since the infant MMR's characteristics have been linked to inter-individual differences in language development (Gu & Bi, 2020; Volkmer & Schulte-Körne, 2018), it has been discussed as a potential predictor of impending language difficulties. Indeed, various studies reported associations with later language difficulties for MMRs to different types of auditory information at different time-points across development (Leij et al., 2013; Schaadt et al., 2015). However, to reliably utilize the infant MMR as a predictive measure for language development, a systematic investigation of the MMR's maturation depending on stimulus-type is needed. As a first step, we longitudinally explored the maturation of the infant MMR to deviation in speech and non-speech features. In a multi-feature paradigm, we obtained MMRs to consonant, vowel, vowel-length, and pitch changes, when infants (n = 59) were 2, 6 and 10 months old. To specifically tackle the maturational trajectory of the respective MMRs, we applied separate second-order latent growth curve models for each deviant type. Results showed positive-going MMRs to all deviant types and across all assessment points, typically observed in infants (Dehaene-Lambertz, 2000; Kailaheimo-Lönnqvist et al., 2020). However, MMR amplitudes decreased over time towards a negativity in differently shaped growth curves for each deviant. The pitch and vowel-length MMRs decreased linearly across age, becoming less positive (i.e., more negative); the consonant MMR initially became less positive (i.e., more negative), then stabilized between 6 and 10 months; while the vowel MMR showed a u-shaped trajectory, first increasing (more positive) until 6 months and then declining until 10 months (less positive, i.e., more negative). These results demonstrate that infant speech discrimination matures in different rates and amplitude trajectories across the first year of life, dependent on the studied feature. We thus argue that the MMR's stimulus-dependent maturational trajectory needs to be considered when aiming for reliably predicting later language development. References Dehaene-Lambertz, G. (2000). Cerebral Specialization for Speech and Non-Speech Stimuli in Infants. J Cogn Neurosci, 12(3), 449–460. Gu, C., & Bi, H.-Y. (2020). Auditory processing deficit in individuals with dyslexia: A meta-analysis of mismatch negativity. Neurosci Biobehav Rev, 116, 396–405. Kailaheimo-Lönnqvist, L. et al. (2020). Infant event-related potentials to speech are associated with prelinguistic development. Dev Cogn Neurosci, 45, 1-10. van der Leij, A. et al. (2013). Precursors of Developmental Dyslexia: An Overview of the Longitudinal Dutch Dyslexia Programme Study. Dyslexia, 19(4). 191-213 Schaadt, G. et al. (2015). Present and past: Can writing abilities in school children be associated with their auditory discrimination capacities in infancy? Res Dev Disabil, 47, 318-333. Volkmer, S., & Schulte-Körne, G. (2018). Cortical responses to tone and phoneme mismatch as a predictor of dyslexia? A systematic review. Schizophr. Res., 191, 148–160.

Topic Areas: Development; Speech Perception

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Speech perception slopes across the first year of life: Maturation of consonant perception, but not vowel perception, predicts lexical skills at 12 months

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Consonants and vowels differentially contribute to lexical acquisition across the first year of life, with a preferential role of consonants from around 8 months (Nishibayashi & Nazzi, 2016; Poltrock & Nazzi, 2015). Infants' differential reliance on consonants versus vowels in word recognition has been shown to predict later lexical outcome (Von Holzen et al., 2018; Von Holzen & Nazzi, 2020). This predictive value, however, has not yet been evaluated for infants' longitudinal trajectories of consonant and vowel perception. We here aimed to study brain markers that can capture perceptual changes before infants show vowel or consonant preferences in word recognition behaviorally. We examined longitudinally (at ages 2, 6, and 10 months) whether infants' (n= 59) maturation trajectories of vowel and consonant discrimination differentially predict their later lexicon. At each age, we measured infants' discrimination abilities in a multi-feature paradigm by means of the electrophysiological mismatch responses (MMR) to consonant and vowel deviants. At 12 months, we assessed infants' lexical skills via the German version of the Communicative Development Inventories (parental questionnaire; Grimm & Doil, 2000). Using separate second-order latent growth curve models for each deviant type, we tested the maturational slopes of vowel and consonant MMRs between 2 and 10 months as predictors of word production and perception at 12 months, controlling for the effect of individual MMR amplitudes at each assessment. The consonant MMR slope significantly predicted word perception ($p = .003$) and production ($p < .0001$), whereas there were no effects for the vowel MMR slope for perception ($p = .867$) or production scores ($p = .502$). Note that only for consonants at 2 months, the single time point MMR predicted later receptive ($p < .0001$) and productive lexicon ($p = .006$), while the MMR's maturational slope had an additive predictive value. These results confirm a prominent role of consonant, but not vowel, discrimination for word learning from early on. Given that a behavioral preference for consonants in word recognition only evolves towards the end of the first year (Nishibayashi & Nazzi, 2016; Poltrock & Nazzi, 2015; Von Holzen et al., 2018; Von Holzen & Nazzi, 2020), our study points to a much earlier predictive value of consonant perception and to a particular role of the longitudinal maturation of this perceptual skill in lexical acquisition. References: Grimm, H., & Doil, H. (2000). ELFRA - Elternfragebögen für die Früherkennung von Risikokindern. Hogrefe. Nishibayashi, L.-L., & Nazzi, T. (2016). Vowels, then consonants: Early bias switch in recognizing segmented word forms. Cognition, 155, 188–203. Poltrock, S., & Nazzi, T. (2015). Consonant/vowel asymmetry in early word form recognition. Journal of Experimental Child Psychology, 131, 135–148. Von Holzen, K., & Nazzi, T. (2020). Emergence of a consonant bias during the first year of life: New evidence from own-name recognition. Infancy, 25(3), 319–346. Von Holzen, K., Nishibayashi, L.-L., & Nazzi, T. (2018). Consonant and Vowel Processing in Word Form Segmentation: An Infant ERP Study. Brain Sciences, 8(2), 24.

Topic Areas: Development; Speech Perception

Slide Slam Session I

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Investigating listening effort using neural speech tracking and alpha oscillations: the effects of acoustic distortion and language of materials

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Previous research has suggested that background noise or acoustic distortion (e.g., noise vocoding) can disrupt neural tracking of speech in the auditory cortex (e.g., Peelle et al., 2013). In contrast, our previous work has demonstrated that challenging listening conditions increase listening effort, thereby enhancing neural tracking (Song & Iverson, 2018; Song et al., 2020); this was found in non-native listeners compared to native listeners. The aim of the present study was to clarify the inconsistent findings in the following ways: we used acoustic distortion that preserves F0 as well as the broad-band amplitude envelope; noise vocoding used in previous research eliminates periodicity. Moreover, we examined within-subject differences in neural tracking for native versus non-native languages, as well as differences between native and non-native listeners. Lexical processing was also measured using N400 in order to examine speech processing at multiple stages, along with alpha power, which is thought to be an index of listening effort (e.g., Obleser et al., 2012). Electroencephalogram (EEG) recordings were made from native Korean speakers of English when listening to English and Korean sentences; native English speakers participated in the English part of the experiment. There was a competing-talker background in all conditions, but the target was either normal or was adaptively distorted in a way that reduced spectral detail of the target speech while preserving both F0 and the broad-band amplitude envelope. The results demonstrate that acoustic distortion increases neural tracking of speech acoustics in early auditory-cortical processing, likely due to increased listening effort. The degree of neural tracking was likewise higher for L2 than for L1 speech, whereas listeners had decreased lexical processing (i.e., smaller context-related differences in N400) for L2 than for L1. These language differences were found within individuals (i.e., Korean vs. English sentences) as well as between listener groups. Preliminary results of a time frequency analysis showed greater alpha power when listening to L2 (within-subject differences), confirming that listeners deploy greater attentional resources in that condition. However, alpha power increased with increasing signal-to-noise ratios. Our findings demonstrate how increased listening effort affects auditory and lexical processing, but further investigation is needed to fully understand the results of the time frequency analysis.

Topic Areas: Speech Perception; Perception: Auditory

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Neuronal long-range temporal correlations are correlated with scaling laws of speech envelopes

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Magneto- and electroencephalographic (M/EEG) studies have demonstrated the cortical entrainment to syllabic rhythm of speech and linguistic structures of phrases. Previous studies on cortical entrainment to speech were mainly based on fitting a response function describing the linear mapping between natural speech and M/EEG signals. We aimed to extend the understanding of cortical entrainment by using the detrended fluctuation analysis (DFA), which have been widely applied to the detection of long-range temporal correlations (LRTC) in time series, such as M/EEG signals, the amplitude envelopes of M/EEG and response times. In the present study, twelve adults who are native speakers of Mandarin Chinese participated in a speech comprehension task, in which they would hear normal speeches or noise-vocoded speeches which were vocoded with 16 channels or 4 channels. Speech materials were based on a large-scale Chinese corpus (Sinica COSPRO corpus). The results demonstrated that the LRTC scaling exponents of MEG signals were significantly correlated with those of speech envelopes. This finding supports the prediction that the power-law scaling of brain activity and speech envelopes would be correlated with each other. Furthermore, we investigated whether the intelligibility of speech sound (normal, 16 channels, and 4 channels) can be predicted from spatial patterns of LRTC scaling exponents of MEG signals. Therefore, multivariable pattern analyses (MVPA) were conducted to predict stimuli types. The results demonstrated that scalp distributions of LRTC scaling exponents of MEG signals can decode the intelligibility of speech stimuli.

Topic Areas: Speech Perception; Perception: Auditory

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A unifying computational account of temporal processing in natural speech across cortex

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In order to understand natural speech, the human cortex must process information at several different timescales. Prior work suggests that cortex processes temporal information through a hierarchy of representations from short-timescale regions like auditory cortex to longer timescale regions such as prefrontal cortex. While some computational accounts of timescale phenomena have been proposed, none directly model and predict responses to natural stimuli. Moreover, these accounts collapse data across individuals and brain regions, limiting the models' predictive power and resolution. We propose a computational account that predicts responses to ecologically-valid natural language stimuli and implicitly captures the timescale hierarchy, while providing all the benefits of single-subject, single-voxel predictions across cortex. Interpreting the estimated models further suggests a diversity in voxel function across cortex, tied to each region's timescale. We first built a multi-timescale recurrent neural network (MT-RNN) trained as a self-supervised language model. Each unit in MT-RNN was made to integrate temporal information at a fixed timescale. Then we extracted representations of the stimulus from each unit of the MT-RNN in order to build multi-timescale encoding models (MT-EMs). MT-EMs were trained with fMRI data from 7 subjects listening to 5 hours of narrative English stories. The encoding model for each voxel learned to predict BOLD responses from the MT-RNN representations with ridge regression. We found that MT-EMs significantly predicted brain responses on a held-out dataset in much of the temporal lobe, precuneus and prefrontal cortex. We then investigated whether MT-EMs could capture known timescale differences across regions. First we estimated every voxel's processing timescale based on its regression weights for MT-RNN units. This produced fine-grained single-subject maps of voxel timescales that corroborated previous reports of a temporal hierarchy. Next, we simulated experimental manipulations from previous neuroimaging studies that also investigated temporal context effects [Lerner 2011; Yeshurun 2017; Chien 2020]. These in silico experiments tested timescale properties of both the MT-RNN itself, as well as voxels in cortex using MT-EMs. In all experiments, the MT-RNN units exhibited temporal context effects in accordance with their assigned timescale-- short-timescale units responded to local, word-level information and retained information for short durations while long-timescale units encoded global, paragraph-level information and retained information over long durations. To measure temporal effects of single voxels, we used MT-EMs to simulate fMRI responses to each experimental manipulation. Despite learning to only predict BOLD responses in a passive listening task, MT-EMs could successfully replicate temporal context effects across cortex in nearly every test. While auditory cortex was sensitive to word-level manipulations and integrated information quickly, precuneus and prefrontal cortex integrated information slowly and were sensitive to long-timescale manipulations. Lastly, we probed the MT-RNN representations to infer what linguistic information was encoded in different timescale units. We found that the short-timescale units capture token-level information like part-of-speech or entity type, while longer timescales capture discourse-level information like narrative topic. Combined with the implied computational isomorphism between the MT-RNN and cortical processing, these results provide new evidence that different timescale regions in the brain may preferentially process different linguistic features.

Topic Areas: Computational Approaches; Speech Perception

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Spanish-English Bilinguals' Phonetic Perception in Speech-Shaped Noise

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INTRODUCTION. Real-world listening situations are often noisy, and speech comprehension in these acoustically adverse situations is challenging, especially for bilingual listeners communicating in their second language (L2). Indeed, prior studies have demonstrated that compared to monolinguals, bilinguals have less accurate speech recognition when listening to their L2 in the presence of background noise (e.g., Mayo et al., 1997; Garcia Lecumberri & Cooke, 2006). Here we investigated how the presence of background noise influences Spanish-English bilinguals' percepts along a /va/-/ba/ continuum, compared to English monolinguals. The phonemes /v/ and /b/ were selected to capitalize on the fact that Spanish phonology maps /v/ onto /b/, whereas English makes a clear distinction between these two phonemes. Another goal of this study was to examine whether bilinguals' age of English acquisition plays a role in their perception along the /va/-/ba/ continuum. METHODS. The continuum from /va/ to /ba/ comprised five consonant vowel (CV) stimuli. On each trial, one CV stimulus was presented in Quiet or was embedded in speech-shaped noise at one of three signal-to-noise ratios (SNRs): +6 dB, 0 dB, and -6 dB. Spanish-English bilingual (n=36) and English monolingual (n=13) participants reported whether they perceived /ba/ or /va/ on each trial. Since Spanish phonology maps /v/ on /b/, we hypothesized that Spanish-English bilinguals would perceive /ba/ more often—especially towards the /va/ end of the /va/-/ba/ continuum and in noisier conditions—than English monolinguals. We also hypothesized that bilingual participants with a later age of English acquisition would perceive the stimuli as /ba/ more often, especially in noise, than the bilinguals with an earlier age of English acquisition. RESULTS. Overall, across both monolingual and bilingual groups, the SNR condition and the CV stimulus step (i.e., along the /va/-/ba/ continuum) significantly affected perception (both effects: $p<0.001$). There was also a significant interaction between the SNR condition and CV stimulus step ($p<0.001$). Overall, participants perceived /va/ significantly more often than /ba/ in the Quiet condition than in the other three noise conditions, with no differences observed during the three noise conditions. Furthermore, collapsing across the SNR conditions, participants perceived /ba/ more often as the continuum progressed from /va/ towards /ba/. Surprisingly, the bilinguals perceived /va/ significantly more often overall (mean=54%) than the monolinguals (mean=44%; $p=0.006$). This group difference was evident even in the Quiet condition, especially when participants listened to CVs towards the /ba/ side of the continuum. No interactions between group and SNR condition were observed, suggesting that SNR did not modulate this group difference. Finally, age of English acquisition did not drive these group differences, as there were no significant differences in perception between early and late sequential bilinguals (who learned English before and after age 5 years, respectively). CONCLUSION. These results suggest that the presence of the English-specific phoneme /v/ in the current task may have resulted in a phonetic recalibration process, whereby bilinguals' perceptual phonetic boundaries can dynamically shift depending on language context. Follow-up experiments will further explore this phonetic recalibration process and its underlying neural mechanisms in Spanish-English bilingual listeners.

Topic Areas: Multilingualism; Perception: Speech Perception and Audiovisual Integration

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Phonemic category & higher-order acoustic features jointly drive neural response to speech

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Using intracranial EEG recorded during a passive listening task, this study provides evidence that the brain abstracts phonemic category identity from an acoustically variable speech stream, and that it may do so in part using the covariance structure of the stimulus. Intracranial EEG was recorded while ten participants listened to excerpts from the Buckeye Corpus (Pitt et al. 2007), a phonemically segmented and labeled corpus of American English conversational speech. Stimulus-timelocked broadband LFP (0.1-170Hz) and high gamma power (HGP: z-scored analytic amplitude of 70-150Hz bandpass LFP) were subsequently extracted from the recording. Linear mixed-effects models were fit for each participant, modeling neural activity (HGP or LFP) with electrode channel and excerpt speaker as random effects. Fixed effects were either only spectrographic features, only phonemic labels, or both. Models were compared within response variable type (HGP or LFP) using the Akaike Information Criterion (AIC). All best-fit models carried 100% of the cumulative model weight and had an AIC score >200 lower than other models. For broadband LFP, all participants' data were best fit by the model that included both spectrographic features and phonemic labels. These results demonstrate that broadband LFP contains phonemic category information that is not reducible to speech acoustics. For HGP, eight participants' data were best fit by the model that included only spectrographic features and two participants' data were best fit by the model that included both spectrographic features and phonemic labels. These results indicate that HGP is primarily driven by speech acoustics rather than phonemic category information. The variability in the best-fit model across participants may result from differential electrode coverage across participants and will take follow-up work to assess. Based on these results, maximum noise entropy (MNE) models (Kaardal et al. 2017) were fit to assess what aspects of the stimulus drove the results. These MNE models are logistic functions of a linear combination of the first- and second-order features of the stimulus (the stimulus variance and covariance, respectively). First- and second-order models were fit to the HGP and broadband LFP of each participant for spectrographic stimuli that were either labeled or unlabeled for phonemic identity. For each channel, fit models were used to generate predicted neural responses. Pearson's r was calculated to assess the correlation of recorded vs. predicted responses and transformed using the Fisher Z-Transformation for comparison across conditions. There was a statistically significant interaction between the effect of model order (first vs. second) and label status (labeled, unlabeled) on MNE model prediction quality, with $p<0.0001$ for all subjects, driven by second-order models fit using spectrograms labeled with phonemic identity. The fact that the inclusion of stimulus covariance structure improves model prediction for labeled data beyond the improvement for unlabeled data suggests that stimulus covariance structure and phonemic identity synergistically impact neural response, jointly providing some information not available in either feature alone. Given work showing that the highest magnitude eigenvectors of speech covariance matrices are speaker-dependent (Zhou&Hansen 2005), this interaction may be driven by speaker-specific phonemic normalization. Future work will explore this possibility.

Topic Areas: Speech Perception; Phonology and Phonological Working Memory

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Detecting the N400 ERP using EEG hyperscanning during conversation in both conversation participants and observers

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EEG hyperscanning, which refers to recording simultaneous EEG data from multiple people, are becoming more popular in language cognition research. Studies have mainly focused on neuro-oscillatory dynamics as it is difficult to examine unpredictable occurrences in a highly time-locked manner as necessitated by event-related potential (ERP) studies. We developed EEG hyperscanning methods to detect ERPs in response to words people hear during a conversation. Specifically, we examined if the N400 response differed between hearing low and high lexical frequency words. Twenty pairs of participants had a scripted conversation together while EEG hyperscanning occurred. A key feature of this task is that participants are asked to self-generate the linguistic stimuli themselves by reading lines to each other of a scripted dialogue. Each participants' script contained only their own lines that they said during the scripted dialogue and displayed only simple cues of when it was their partners' turn to speak. Therefore, each participant served as their partners' stimuli delivery system as we only examined the participants responses when they were acting as the listener during the conversational exchanged. A control group of twenty other pairs of participants watched a recording of the same conversations while undergoing EEG hyperscanning. We then transcribed the recorded dialogues to mark the onset times of each word of interest to which ERPs were obtained. There was a significantly greater N400 response to low frequency words in comparison to high frequency words in both groups, replicating previous findings. These results demonstrate that the N400 ERP experiments can be conducted using stimuli generated by experimental participants engaged in conversation as N400 characteristics and effects were comparable both when participants self-generated the stimuli themselves by having a scripted conversation and when participants watched video recordings of the scripted conversation. This opens up new opportunities for more naturalistic ERP studies of language.

Topic Areas: Speech Perception; Perception: Auditory

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Self-paced reading and ERP studies on Chinese sentence processing by prelingually Deaf learners

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Deaf individuals often have limited access to auditory language input, resulting in incomplete acquisition of the spoken/written language. In particular, Deaf readers tend to be less sensitive to syntactic violations compared to semantic violations (Skotara et al. 2012; Mehravari et al. 2017). Previous studies suggest that language learners with limited proficiency, including deaf signers with impoverished early language (Cheng & Mayberry 2020), often show over-reliance on semantic cues when there are conflicting cues in the sentence. Studying how prelingually Deaf learners resolve conflicting cues in real time can shed light on the nature of the language learning/processing difficulties in this population, and also reveal the role of fully accessible early language on brain development. The current study aims to examine how prelingually Deaf adults in China process written Chinese sentences with canonical and reversed semantic roles. We have two research questions: 1) Are prelingually Deaf learners more likely to rely on event plausibility when comprehending sentences with reversed semantic roles? 2) If so, what are the real-time processing mechanisms that contribute to their comprehension performance? We first gathered behavioral data using a self-paced reading task (key pressing with moving window, implemented in Ibex), with a sentence plausibility question ('Does this sentence make sense?') following each sentence. We used a factorial design with two factors, animacy order (Animate-inanimate, AI vs. Inanimate-animate, IA) and Plausibility (Plausible vs. Implausible), using the SOV BA-construction and the OSV BEI-construction in Mandarin, with 15 trials in each condition and equal number of fillers. Compared to the hearing controls (N=42, mean age=25.0), Deaf participants who are prelingually Deaf and did not use hearing aids before age 3 (N=39, mean age=31.21) showed lower accuracy especially when the sentences are implausible (t=-2.470*). This suggests that similar to previous findings, Deaf readers rely more on event plausibility even when it conflicts with the syntactic cue. However, their reading time were longer at the key verb region when the sentence is implausible (t=4.525***), with an additional spillover effect in the following word (t= 1.973*), even when their responses were incorrect. In contrast, hearing participants showed no slowdown across all conditions. Instead of entirely missing the syntactic cues, Deaf readers showed increased processing difficulties, which may contribute to their lower accuracy. These findings suggest that prelingually Deaf learners are sensitive to syntactic cues, but they struggle with resolving conflicting cues in real time. To further examine the processing difficulties, we are currently conducting an ERP experiment using SOV BA-construction sentences that are either plausible, semantically reversed, or with an incompatible verb. We aim to recruit 20 Deaf and 20 hearing participants. Given the observed processing difficulties from the self-paced reading task, there are two possibilities for the semantically reversed sentences. If the processing difficulties come from reanalyzing the sentence, we would expect an increased P600 effect in the Deaf group when compared to the hearing group. Alternatively, if the processing difficulties come from lexical surprisal effects of the verb, then we should expect an increased N400 effect.

Topic Areas: Syntax; Disorders: Developmental

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Neural substrates of phonological processing in Chinese-English bilingual children

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This study is to determine how bilingualism influences children's neural architecture for learning to read. We address the question by examining phonological literacy skills in English, a second language for Chinese-speaking Taiwanese first grade children. In adult speakers, Chinese spoken and written word processing engages a more equitable division of labor between semantic and phonological pathways due, in part, to the highly homophonous nature of the language and its orthographic representation. To understand how these cross-linguistic differences influence bilingual development, we asked 10 Chinese monolingual and 20 Chinese-English bilingual first graders to complete an auditory phonological judgment tasks during fNIRS (functional Near Infrared Spectroscopy) neuroimaging. During the imaging task, children heard three words and decided which of the two matched. The task included two levels of difficulty requiring either syllable (easy) or phoneme (difficult) segmentation. Monolingual participants completed the task in Chinese whereas the bilinguals completed it in both languages. Neuroimaging results revealed task difficulty effects, with stronger neural activation for the easy condition in the left inferior frontal gyrus. Yet, this difficulty effect was only present in English of the bilinguals but not in Chinese of either bilinguals or monolinguals. This finding suggests cross-linguistic difference in the development of phonological processes for learning to read. Moreover, bilingual speakers develop language-appropriate sensitivity for each of their languages.

Topic Areas: Multilingualism; Phonology and Phonological Working Memory

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The effects of white noise and dopamine modulation on novel word learning in healthy young adults.

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The administration of the dopamine precursor levodopa and the behavioural manipulation of auditory white noise are both novel approaches that may potentially benefit cognitive function, including new word learning in healthy adults. It has been suggested that white noise benefits non-linguistic learning by engaging a dopaminergic neural network, however this proposed link is yet to be examined with linguistic learning such as new word learning. The aim of this study was to investigate the influence of white noise on new word learning in healthy young adults and examine whether this influence is modulated by changes in dopamine. Forty-nine healthy young adults (mean age= 23.9 ± 3.7; age range 19-33; 35 females, 14 males) participated in this double-blind, placebo-controlled, mixed-groups trial. Participants attended a single session where they completed a baseline word learning task, ingested a single placebo or levodopa capsule (random allocation) and subsequently completed an in-scanner (fMRI) associative novel word learning task. Participants were presented with 40 coloured pictures of aliens, each paired with a 3-word name. All names comprised a novel word followed by two attributes (e.g., floobs wise silent). The 40 aliens were presented in 2 learning blocks of 20 aliens, with all aliens within each block presented 3 times. Each presentation of the 20 aliens was followed by an immediate in-scanner recognition task. Half of the participants were randomly assigned to listen to white noise (set at 70 dB) during the first learning block and the other half during the second learning block. During the in -scanner recognition tasks, participants were asked to select the correct first name for each alien out of 4 choices. Delayed novel word recall and recognition, and attribute recognition were also assessed 25 minutes later. Linear mixed model analyses were performed using SPSS with recall/recognition accuracy as the dependent variables. Fixed factors included group (placebo and levodopa) and noise (silence and white noise). Participants were included as a random factor and baseline word learning ability was included as a covariate. Main effects were followed by Bonferroni-corrected post-hoc tests and a p value <.05 was used to determine significance. No main or interaction effects involving group and noise were found when examining immediate and delayed recognition accuracy data. In contrast, while the analysis of delayed novel word recall revealed no main effect of noise and no group-by-noise interaction, a main effect of group was evident $F(1, 93)=6.647$; $p=.012$, reflecting higher recall accuracy in the levodopa group relative to the placebo group. Irrespective of white noise, levodopa benefited delayed novel word recall in healthy young adults. Further analysis using the fMRI data will allow elucidation of the neural mechanisms underpinning the beneficial effects of levodopa on novel word learning.

Topic Areas: Meaning: Lexical Semantics; Phonology and Phonological Working Memory

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Modulation of the N400 by morphological composition and lexical access: An ERP study of Japanese derived nouns

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Previous neurolinguistic studies reported that lexical access and morphological composition elicited cortical activation around 300-400 ms after the word onset (M350/N400) in the middle and superior temporal gyri. Here, we examined the processing of the two types of Japanese nouns derived from adjectives (derived -sa noun: ama-sa, sweetness, derived -mi noun: ama-mi, sweetness). While the -sa suffix is extremely productive, -mi suffix attaches to 30 adjectives. Previous studies proposed that the native speakers decomposed the derived -sa nouns into morphemes, while they memorized the derived -mi nouns and cannot decompose into morphemes, suggesting that only the former nouns show the modulation of the cortical activation M350/N400 reflecting transition probability (TP) between the adjectival stem and suffix. In the present study, we examined whether these two types of derived nouns were processed by the common neural mechanism or two distinct systems. We recruited 20 right-handed native speakers of Japanese (10 males, 22.8±4.5 yrs.). We used 25 items for each of the derived -sa nouns, derived -mi nouns, non-derived -sa nouns (ookami, wolf), and non-derived -sa nouns (nagisa, beach), as well as the same number of nonwords (total 200 items). The participants performed a visual lexical decision task. Because we were interested in the derived nouns, we targeted the derived -sa nouns and -mi nouns for the following EEG analyses. We used a 64-electrode EEG system (Nihon-Kohden) for the EEG data collection and MNE-Python for the data analysis (Gramfort et al., 2013). Since our primary target was the N400, we selected left centro-parietal electrodes (P5, CP3, CP5) for the region of interest. The analysis time window was restricted to 300-400 ms after the word onset. A two-way repeated-measures analysis of variance (rANOVA) (suffix × derivedness) for the accuracy showed the significant main effects of suffix and derivedness, as well as the significant interaction (suffix: $p = .0007$; derivedness: $p < .0001$; interaction: $p < .0001$). A two-way rANOVA for the RTs also showed the main effect of derivedness and the significant interaction were significant (derivedness: $p = .0026$, interaction: =.0010), but the main effect of suffix was not ($p = .70$). These results suggest that the derived nouns had lower processing loads. For the ERP data, we examined whether logarithmic LogTP between the adjectival stem and suffix, as well as the word length and the ultima (the last syllable of a word, -sa or -mi), modulated the N400 using a linear mixed-effect model (lme4 and lmerTest packages on R). We included random intercepts for the subject and stimulus to account for participant-specific variability and item-specific idiosyncrasies. We found that the model with the word length and LogTP showed the lowest AIC, indicating that both the word length and LogTP between morphemes modulated the N400. Moreover, we found that the model with the word length and token frequency showed the second-lowest AIC, suggesting that the lexical access modulated the N400 as well. These results demonstrated that both types of Japanese-derived nouns have the same processing stages, i.e., decomposition and recombination of morphemes.

Topic Areas: Morphology; Reading

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The transition from vision to language: distinct patterns of functional connectivity for sub-regions of the visual word form area

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Text evokes a response in a region of ventral occipitotemporal cortex, termed the Visual Word Form Area (VWFA; Cohen et al., 2000). Recent findings suggest that this word-selective cortex comprises at least two distinct subregions that process different aspects of written language: the more posterior VWFA-1 is sensitive to visual features, while the more anterior VWFA-2 processes higher level language information like lexical properties (Lerma-Usabiaga et al., 2018; White et al., 2019). Complementary evidence suggests that these sub-regions differ from each other not only functionally, but also in their cortical microstructure and white matter connectivity. Here, we explore whether these two sub-regions exhibit different patterns of functional connectivity, and whether these patterns have relevance for reading ability. A sample of 90 children and adolescents was selected from the HBN database (Alexander et al., 2017; 47 males, mean age 13±3.5y, range 6.5-20y). Selection criteria included the availability of two high quality resting state functional runs and a reading assessment (Wechsler Individual Achievement Test, WIAT). Subjects were included only if each of their functional scans had sufficient quality in terms of both SNR (>1.5) and motion (mean framewise displacement < 0.5mm). For each resting-state run, 375 volumes were collected with the following parameters: TR=820ms, TE=30ms, resolution=2.4mm. Resting-state data were preprocessed with C-PAC (Craddock et al., 2013) and then analyzed using the CONN toolbox (Whitfield-Gabrieli, S. & Nieto-Castanon, A., 2012). The average locations of VWFA-1 and VWFA-2 were defined based on previously reported coordinates (Lerma-Usabiaga et al., 2018). Whole brain functional connectivity analysis revealed that VWFA-1 was more strongly correlated with bilateral visual regions including large portions of ventral occipitotemporal cortex and posterior parietal cortex (FDR corrected at $p < 0.05$). In contrast, VWFA-2 was more strongly correlated with language regions in the frontal and lateral parietal lobes, in particular the bilateral inferior frontal gyrus (IFG), left superior frontal gyrus (SFG) and bilateral intraparietal sulcus (IPS). Next, for each subject we extracted the connectivity strength (pearson's r) from each of the clusters that were differentially associated with VWFA-1 and VWFA-2 in the group analysis and examined whether connectivity strength was associated with individual reading skills. This analysis revealed a striking dissociation: Reading ability was associated with connectivity strength between left IFG or left IPS and VWFA-2, but not with connectivity strength between these regions and VWFA-1. Further, connectivity between the same IPS cluster and VWFA-1 was associated with age, but not with reading ability. In sum, our findings support the distinction between sub-regions of the VWFA, showing that adjacent regions are coupled with distinct networks. In addition, we show that the strength of these connectivity patterns is associated with reading ability, such that better readers have stronger connectivity between frontal language regions and VWFA-2, but not VWFA-1. These findings reveal an elegant correspondence between white matter anatomy, functional connectivity, cortical computation and the development of reading skills.

Topic Areas: Reading; Development

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Sulcal morphology in ventral temporal cortex and the development of reading skills

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Literacy learning builds onto neural and cognitive architectures that are partially in place by the age children start literacy instruction. Many cognitive factors have been reported to predispose a child to acquire adequate reading skills, such as phonological awareness and rapid naming abilities. At the neural level, previous research shows that nearby anatomical locations in left ventral temporal cortex (VTC) are associated with reading. The occipito-temporal sulcus (OTS) notably hosts a cortical region that processes visual words, and its morphology predicts reading skills in 10-year-old children and adults (Borst et al., 2016; Cachia et al., 2018). A functional region in the mid-fusiform gyrus on the other hand, seems to process graphemes, critical for phonological decoding (Bouhali et al., 2019). However, none of these studies considered the morphological role of the mid-fusiform sulcus (MFS), recently shown to be a critical microstructural and functional landmark in VTC (Grill-Spector and Weiner, 2014). Here, we tested the direct hypotheses that (i) the structure of the left OTS would be prospectively associated with reading skills at early stages of literacy acquisition, and (ii) left MFS and OTS morphology would show a double dissociation consistent with their respective functional roles in orthographic processing; the MFS would be more related with phonemic decoding skills, while the OTS would better predict lexical reading skills. In order to test these hypotheses, we studied the associations between OTS and MFS morphology and the development of reading skills in a cohort of 50 children followed longitudinally from age 5, at the onset of literacy instruction, to age 8, when children are expected to have become fluent readers. Specifically, we identified the OTS and MFS at both ages in each child. We then investigated the relationship between reading (timed pseudo-word and real word reading), and several morphological features of bilateral OTS and MFS (number of sulcal interruptions, sulcal length, mean sulcal depth and cortical thickness). Consistent with our first hypothesis, we found that overall reading skills at age 8 were reliably associated with cortical thickness of the left OTS measured both at ages 5 and 8, when controlling for reading-related cognitive skills and standard control variables. Other sulcal properties did not show such reliable associations. With regard to our second hypothesis, we observed that pseudo-word reading scores at 8 were indeed associated with lower mean sulcal depth of the left MFS both at ages 5 and 8, over and above word reading and other cognitive precursors of reading. However, we did not observe a stronger association of OTS morphology with real word reading than with pseudo-word reading, maybe owing to the limited reliance on lexical reading strategies in 8-year-old readers. This work furthers our understanding of the interactions between early- and late-developing features of sulcal morphology of the VTC and the early development of reading skills during childhood.

Topic Areas: Reading; Development

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Possibly Predictive Potentials: an ERP Investigation into Word Form Preactivation

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While evidence continues to accrue for word form prediction during sentence processing, potential processing limits on lexical preactivation are still being established. Some prediction-by-production accounts propose that during language comprehension, word form prediction occurs via the production system, by which semantic concepts are activated, followed by lexeme selection, and subsequent prediction of anticipated upcoming word forms. Positioned at the end stage of this processing sequence, word form preactivation would be subject to available processing time and would critically hinge on preceding semantic preactivation. To test this proposal, we developed an event-related brain potential paradigm that relied on alliterative low constraint sentences continued by either alliteration-consistent or inconsistent critical words of equally low expectancy. Sentences like, 'Becky's bewildered beagle barked before beggars/workers entered the tunnel' were presented at a serial visual presentation rate of 2 words/s while brainwaves were recorded. A significant N400 amplitude reduction (300-500 ms) was observed to alliterative relative to non-alliterative continuations. These results suggest that even in the absence of strong semantic predictions, readers are able to preactivate form features of likely upcoming words during online sentence comprehension at reading rates faster than some prediction-by-production proposals would allow (e.g., Ito et al., 2016; Pickering & Gambi, 2013).

Topic Areas: Reading; Meaning: Lexical Semantics

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Structure-function relationships and individual differences in reading

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Reading ability has been associated with brain activation and cortical structure, but few studies have examined associations between cortical structure and reading-related brain activation with respect to reading. This leaves a gap in our understanding of neurobiological mechanisms that link cortical structure to reading ability. Here, we examine relationships between cortical thickness (CT), reading-related activation, and individual differences in reading ability to better understand these mechanisms. 73 participants (ages 5-9) completed behavioral assessments of reading and anatomical and functional MRI. Reading ability was measured as a composite of the Letter-Word Identification and Word Attack sub-tests of the Woodcock Johnson Tests of Achievement-III. CT was measured from T1-weighted anatomical MRI scans using Freesurfer. A passive print and speech localizer fMRI task was used to elicit reading-related activation. First, we tested the correlation between cortical thickness, reading-related brain activation, and reading ability in a region of the left superior temporal gyrus (STG) in which we previously identified a significant positive correlation between CT and reading ability (Perdue et al., 2020, Cerebral Cortex). Next, we conducted an exploratory analysis to identify regions of the brain that showed print-specific activation (print > symbol strings contrast). We then tested correlations among cortical thickness, print-related activation, and reading ability in the resulting activation-based regions-of-interest. Age and sex were included as covariates in all correlation models. Results for the analysis of the left STG ROI revealed a non-significant association between CT and reading ability (r=.228, p=.053); no significant correlations with print-related activation were observed in this region. Regions of significant print-specific activation were found in the left occipito-temporal (OT) cortex, left superior temporal sulcus (STS), left precentral gyrus (PreG), and left supplementary motor area (SMA) (p<.05, cluster level FWE-corrected). CT was negatively correlated with reading-related activation in the STS (r=-.246, p=.036), but neither CT nor print activation in the STS were related to reading ability. CT in the left PreG was positively correlated with reading ability (r=.250, p=.033), but no associations with print-related activation in this region were found. No significant correlations were found in the left OT or SMA clusters. Overall, we found only one significant association between CT and reading-related activation in the left STS. The lack of structure-function relationships in the other ROIs shows that CT does not have a clear, direct relationship to reading activation. Notably, no significant correlations between reading-related activation and reading ability were observed, suggesting that although print-related activation could be localized using our task, the degree of activation elicited was not sensitive to individual differences in reading ability in our sample of low- to above- average readers. Thus, links between CT, reading activation, and reading ability may be task-dependent. Other functional measures such as connectivity or response variability may better account for relationships between CT and activation. Alternatively, reading-ability-related effects in CT may reflect anatomical properties of reading network development that are indirectly related to functional processing of print.

Topic Areas: Reading; Methods

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Short animated movies elicit text-selective neural responses in pre-reading children

Iliana I. Karipidis[1], Emily Kubota[1], Sendy Caffarra[1,2], Maya Yablonski[1], Jason D. Yeatman[1]; [1]Stanford University, [2]Basque Center on Cognition, Brain and Language

Studying the neurobiology of language in preschool children with functional magnetic resonance imaging (fMRI) is challenging; head motion causes severe signal artifacts and young children often get distracted during monotonous fMRI tasks. When watching a movie during fMRI acquisition children's attentiveness increases, which leads to decreased head motion compared to task-free fMRI or repetitive well-controlled experiments (Vanderwal et al., 2019). Naturalistic movie-watching paradigms have been successfully used to localize math-related brain activation and have been shown to be comparable to traditional functional localization tasks (Catlon & Li, 2013). Here, we used a movie-watching fMRI paradigm to localize functional brain responses to text and test the effects of language vs. literacy intervention programs. We designed a short movie (196s) that encompassed a sequence of short cartoon clips. Approximately half of the movie included written text, in the form of single words or letters which were either matching concurrently presented speech/song or not. FMRI data were collected while a group of pre-reading children (n=48; mean age=5.25y±0.28) watched the movie at two time points: (1) before and (2) after an intensive 2-week intervention program involving direct instruction in either (a) the foundations of literacy (n=24) or (b) oral language comprehension and grammar (n=24). Two runs of 98 volumes were acquired at each time point on a 3T Siemens scanner (TR=2s, TE=30ms, 33 slices, 3.5 mm3) along with a T1-weighted image. Following preprocessing with FMRIPREP, volumes with scan-to-scan framewise displacement >0.9mm were flagged to perform scrubbing. 34 participants met the criterion of <10% flagged volumes per run and were included in the analysis. We fit a general linear model with three conditions: movie segments with no text, with text congruent to speech, and with text not congruent to speech. An additional regressor modeled effects of visual and auditory characteristics of the different cartoon clips, along with 11 nuisance regressors. Group analysis (FWEcor p<0.05) revealed that across both time points activation for movie segments containing text compared to text-free segments was stronger bilaterally in the superior temporal gyrus (STG) and ventral occipitotemporal cortex (vOTC). Comparing segments of text with and without matching speech showed higher activation bilaterally in the vOTC for text with matching speech and higher bilateral activation in the STG for text with no matching speech. Text sensitivity in the left vOTC before intervention was correlated with individual gain in alphabetic knowledge during intervention (r=0.39, p=0.026). These results demonstrate that a short naturalistic movie-task can elicit text-specific activation in the vOTC, the part of the visual cortex that includes the visual word form area and is known to rapidly develop specialization to written language after reading instruction (Brem et al., 2010). In addition, movie segments with text also increased activation in the STG, a central brain area for language processing, phonological decoding, and audiovisual integration. This work illustrates how a naturalistic experiment can be used to evaluate neurobiological changes after controlled intervention programs in young children and suggests that text sensitivity in the vOTC could be related to individual behavioral responses to intervention.

Topic Areas: Reading; Methods

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The patterns and pathways of structural connectivity in the human language network

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Advanced tractography research has demonstrated the neuroanatomical basis of the dual pathway streams for language processing including a dorsal pathway subserving repetition and a ventral pathway subserving comprehension. Most previous research has focused on structural connectivity within the perisylvian language regions. However, some brain regions, such as the anterior temporal lobe (ATL) that is crucial for semantic processing and the ventral occipitotemporal regions that are crucial for orthographic processing, have not yet been well integrated into the language structural connectome. Therefore, by utilising probabilistic tractography, this study generated an anatomical map extending out the classical perisylvian language network to include the lateral/ventral ATLs and the occipitotemporal cortex. Crucially, we developed a novel approach to compute average streamlines as representative pathways connecting brain regions. The results replicated and extended previous tractography studies by demonstrating that most brain regions were linked via a single pathway. However, some brain regions especially the frontal and occipitotemporal regions were linked via dual pathways with different weights. The connectivity patterns revealed regional specific connectivity changes. The resultant neuroanatomical map of the language network provided detailed information about, not only whether the language regions connected to each other, but also how they connected. The result provides a neuroanatomical basis for establishing the relationship between functionally associated regions and their structural connections within the language network.

Topic Areas: Language Production; Reading

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Effectiveness of rTMS in treating post-stroke aphasia: Role of stimulation parameters and individual characteristics *Sandbox Series*

Aneta Kielar[1], Dianne Patterson[1], Amelia Guzik[1], Ying-Hui Chou[1]; [1]University of Arizona

Introduction: One of the most deliberating and difficult to treat symptoms of stroke is aphasia. Aphasia is incapacitating because it can affect all aspects of language, including speech production, comprehension, reading and writing. In the recent years noninvasive neuromodulation technique, repetitive transcranial magnetic stimulation (rTMS) has been explored as a potential adjunctive treatment for aphasia. Although the results are encouraging the effectiveness of rTMS in treating post-stroke language deficits varies. These inconsistencies are due to the variations in the stimulation protocols, rTMS parameters and patient characteristics across the different studies. The purpose of this meta-analysis was to examine effectiveness of rTMS in treating post-stroke aphasia and to identify parameters that are associated with the best treatment outcome. Methods: This systematic review and meta-analysis was conducted and reported according to the guidance of the preferred reporting for systematic reviews and meta-analyses (PRISMA) statement (Moher et al., 2009). The protocol CRD42020180104 is available in full on the PROSPERO program website (https://www.crd.york.ac.uk/prospero/display_record.php?ID=CRD42020180104). Results: A total of 24 studies (out of 1971 records) with 567 participants (Mean age = 60.4 years, SD = 5.46, Mean Education = 13 years, SD = .97; 65% Males) meet selection criteria and were included in the meta-analysis. The overall pooled analysis revealed significant SMD of 0.655 (95% CI = [0.481-0.830], z = 7.369, p < .001), indicating medium effect size in favor of rTMS treatment. A moderator subgroup analyses were performed to investigate effects of different patients' characteristics and rTMS parameters on treatment outcomes. The results indicated that stroke chronicity, symptoms severity, speech fluency, and lesion location moderated effect of rTMS on language performance. Although, rTMS improved language abilities in both chronic and subacute aphasia, the effects were the strongest in the subacute stages after the stroke. The examination of rTMS parameters indicated that low frequency stimulation to the right IFG (BA45) had most beneficial effect on language abilities. rTMS alone and rTMS augmented with SLT were both effective in enhancing language ability. The examination of language outcomes, indicated that 1 Hz rTMS applied to the right IFG (BA45) had most beneficial effect on naming ability, followed by speech production, repetition and comprehension. Interestingly, the beneficial effect of rTMS on language performance increased at moderate and long-term follow-ups. The results suggest that with 10 to 15 sessions of 1Hz rTMS administered 20-40 min per day over the right IFG, significant language improvements can be observed for up to 12 months. The studies that used fMRI to track effects of rTMS reported significant correlation between shift to the left hemisphere activation and reduced aphasia severity after the intervention with rTMS. Conclusions: The results of our meta-analysis indicate that rTMS alone and combined with the speech-language therapy can be effective in treating language deficit in post-stroke aphasia. Our findings suggest that when planning interventions, it is important to consider the relationship between specific rTMS protocol parameters and individual patient's demographic and clinical characteristics, as well as language outcomes targeted with the treatment.

Topic Areas: Disorders: Acquired; Language Therapy

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Exploring Predictors of Naming Ability in Primary Progressive Aphasia *Sandbox Series*

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INTRODUCTION: Anomia, or word-finding difficulty, is an early and universal feature of primary progressive aphasia, particularly in the logopenic (lvPPA) and semantic variants (sPPA), which disrupt phonological and semantic systems, respectively. Given that cognitive models of naming posit interactive processing of phonological and semantic networks to facilitate lexical retrieval, it follows that differential impairment of these underlying processes should be evident and predictive of naming performance. To examine this hypothesis, we examined the predictive value of phonological and semantic abilities, as well as a metric of speech production abilities, on naming accuracy in 22 individuals with primary progressive aphasia (PPA). To date, we have a sizeable cohort of individuals with the logopenic variant (n=18) , but the semantic cohort is not yet adequate (n=4). Preliminary findings raise some questions worthy of discussion. METHODS: The individuals with PPA reflected a range of aphasia severity (62.7-97.2 WAB AQ). Composite scores were computed for the following skills and compared to a group of age and education matched group of control subjects: a) Phonological awareness/manipulation skills using Arizona Phonological Battery, b) Semantic processing assessed using Pyramids and Palm Trees Test and subtests 47 and 48 of the Psycholinguistic Assessments of Language Processing in Aphasia, and c) Spoken repetition of words/nonwords as a proxy for speech production ability Multiple linear regressions were implemented to examine the predictive value of these three composite scores on naming ability as measured by the Boston Naming Test (BNT), Cambridge Naming Test, and the Naming composite score from the Western Aphasia Battery (WAB). RESULTS: The cohort with PPA was significantly impaired on phonological skills (51.0%), semantic processing (85.9%), and accuracy of speech production (86.0%). Linear regression models were significant for the prediction of naming performance on all three measures. Semantic skills emerged as a significant predictor for performance on the BNT (β =.534, p=.008), the Cambridge Naming Test (β =.786, p=.000), and the Naming composite of the Western Aphasia Battery (β =.740, p=.000). Conversely, phonological skills and speech production did not significantly predict performance on any of the naming measures, despite marked phonological impairment across the cohort. Separate regression models using only those with the lvPPA were not significant. CONCLUSIONS: Despite the disproportionate representation of individuals with lvPPA in our cohort and the overall impairment of phonological processing skills, our findings to date indicate that underlying semantic skills were a strong predictor of naming ability in individuals with PPA. This is in contrast to findings in stroke aphasia that demonstrate a strong predictive association between underlying phonological and semantic skills and naming. These preliminary results motivate continued investigation to better understand the relationship between these central language processes and naming ability in PPA.

Topic Areas: Disorders: Acquired; Phonology and Phonological Working Memory

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Self-Monitoring During Speech Production in a Picture-Naming and Conflict-Inducing Spatial Stroop Task *Sandbox Series*

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Speakers are continuously monitoring their speech as they are speaking. When an error is detected, they may interrupt themselves and repair their utterance. According to the conflict-based monitoring account (Nozari et al., 2011), self-monitoring during speech production occurs through the detection of conflict between opposing responses subsequently resolved by domain-general cognitive control. Previous neuroimaging studies have identified several regions of the cortex, such as the anterior cingulate cortex (Christoffels et al., 2007) and the superior-temporal gyrus (Tourville et al., 2008), as being associated with speech monitoring. In parallel, electrophysiological studies identified the error negativity (Ne), interpreted as a general-purpose response monitoring mechanism (Ries et al., 2011) associated with, but independent, of error detection. Previously, this component has been shown to be present in both correct and error trials, although larger in errors, and onsetting prior to the onset of articulation in studies using scalp electroencephalography. However, these studies generally lacked combined spatial and temporal resolution allowing to identify which brain region supports different aspects of speech monitoring and conflict resolution. In this study, stereotactic electroencephalographic (SEEG) data was acquired from 19 patients undergoing clinical monitoring for intractable epilepsy. Patients performed various language tasks, including a picture-naming task and a conflict-inducing spatial Stroop paradigm. In the spatial Stroop paradigm, participants were presented with arrows pointing right or left on either side of the fixation cross and had to name the direction of the arrow while ignoring where the arrow was located on the screen. Participants were asked to make verbal responses as quickly and as accurately as possible in both tasks. A total of 17 patients participated in the naming task (5F; mean age 33.7 years, SD 11.4) and 15 patients in spatial Stroop (3F; mean age 36.3 years; SD 11.9). Nine patients (2F; mean age 35.6 years; SD 11.9) produced sufficient speech errors (4 or more true errors) during the picture-naming task (mean error rate = 6.1%, SD = 2.7%). Participants were significantly slower in incongruent than congruent trials in the spatial Stroop paradigm (X^2 (1)= 5.72, p=0.017), there was no significant effect on accuracy rates. Brain activity associated with speech monitoring was investigated by focusing on the Local Field Potential (LFP- 0.1-30Hz) activity. Preliminary results show larger activity in errors than correct trials peaking around vocal onset in bilateral middle-temporal gyrus across multiple subjects during picture-naming. In the spatial Stroop paradigm greater activity is seen peaking before vocal onset for incongruent compared to congruent trials in the left frontal cortex, left medial temporal lobe and peaking around vocal onset in bilateral middle temporal gyrus and left superior temporal gyrus (SEEG analysis performed on 8 patients, 6M; mean age 34.2 years; SD 9.6). These preliminary results suggest a role of the left middle frontal and medial temporal lobe in processes preceding speech monitoring, such as response selection, and a role of the bilateral middle-temporal gyrus and left superior temporal gyrus in conflict resolution for speech monitoring during production.

Topic Areas: Language Production; Control, Selection, and Executive Processes

Slide Slam J4 Play Video

Intracranial electroencephalographic signatures of word retrieval in individuals with intractable epilepsy *Sandbox Series*

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Although language production is complex, speakers can select from more than 50,000 words in their mental lexicon to produce 2-3 words per second (Levelt, Roelofs, & Meyer, 1999). Several models have been proposed to illustrate the stages of processing during word retrieval, including Levelt et al. (1999)'s serial processing model and Dell et al. (2013)'s interactive activation model. One question that arises when adjudicating between different models is whether word retrieval processes are serial and confined to a small number of structures (Levelt et al., 1999) or interactive and widespread (Dell et al., 2013). We can probe stages of word retrieval through semantic facilitation and interference, which have previously been reported using picture-word interference with identity primes to trigger facilitation and semantically-related primes to trigger interference (Blackford et al., 2012). Previous work examining word retrieval primarily used non-invasive techniques (e.g., EEG, MEG, fMRI). Using intracranial EEG recordings is better suited to determine whether word retrieval is focal (i.e., Levelt's model) or widespread (Dell et al., 2013) and which brain regions are involved in facilitation and interference because we can access deeper focal activities not accessible using non-invasive techniques as well as combine excellent spatial and temporal resolution. We collected intracranial stereotactic EEG in 7 individuals with intractable epilepsy undergoing invasive monitoring to identify seizure foci (mean age = 30.2 years, SD = 6.03 years). Participants named pictures superimposed with to-be-ignored distractor words that were either semantically-related, semantically unrelated, or the same identity as the image. There was a main effect of condition on reaction time ($\chi2(1,7)$ = , $p = .005$) and error rate ($\chi2(1,7) = 7.70$, $p = .02$). Planned follow-up analyses indicated significantly slower RTs in related than identity ($t = -5.43$, $p < .0001$), marginally slower in related than unrelated ($t = 2.31$, $p = .054$), and significantly slower in unrelated than identity ($t = -3.10$, $p = .006$). Significantly more errors occurred in related than identity (Wald $Z = 2.72$, $p=.017$) and in unrelated than identity (Wald $Z = 2.41$, $p=.041$) with no significant difference between unrelated and related (Wald $Z = -0.40$, $p=.91$). In preliminary iEEG analyses with 3 participants we analyzed bipolar local field potentials and high gamma activity. There was an increased N400 amplitude for identity and related conditions, suggesting early semantic facilitation. Frontal regions (right superior and inferior frontal sulcus) contained both early facilitation (N400 window) and later (starting at 800ms) interference effects. Temporal regions (right superior temporal sulcus) contained both early facilitation (N400) and late response-related effects (peaking between 1000ms and 1400ms post-stimulus onset). Our results suggest that frontal and temporal brain regions assist with lexical activation during early stages of word retrieval, while possible later engagement of cognitive control in the frontal cortex handles effortful processing for related conditions. Future results from this ongoing study will help shed further light on the neural underpinnings of semantic facilitation and interference in speech production.

Topic Areas: Language Production; Control, Selection, and Executive Processes

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FLAIR Enough: Identifying lesion and associated tissue damage and how this affects CBF and behaviour in post-stroke aphasia. *Sandbox Series*

Kimberley Garden[1], Veronika Vadinova[1], Greig de Zubricay[2], Marcus Meinzer[3], Katherine O'Brien[1], Tracy Roxbury[1], Copland David[1], Katie McMahon[2], Sonia Brownsett[1]; [1]University of Queensland, [2]Queensland University of Technology, [3]University Medicine Greifswald

Lesion volume is known to significantly correlate with motor, cognition, visual, and language impairments after stroke. However, the extent to which identified lesions includes white matter damage differs depending on whether the lesion is identified using T1 or FLAIR sequences. Perilesional tissue also plays a part in functional recovery, either in upregulation of residual networks or neurogenesis, when adequately perfused. Reduced cerebral blood flow (CBF) after stroke has been demonstrated in regions past the structural damage of a lesion and is associated with cognitive deficits. Given both the diffuse network involved in language, and the disparate regions involved in other cognitive networks known to contribute to language function under adverse conditions, CBF beyond perilesional areas should be considered when evaluating the contribution of any damage to recovery. Thus, this study aims to: 1) compare mean CBF within grey and white matter and grey matter only in regions surrounding stroke damage, 2) compare CBF between participants and controls, and 3) compare how CBF in these combinations differentially impacts on language performance in the early subacute stage of stroke recovery. Data from participants in the early subacute stage post-stroke and healthy controls underwent structural (high-resolution T1 and T2-FLAIR sequences) and perfusion (pseudo-continuous or pulsed arterial spin labelling; ‘PCASL’, ‘PASL’) imaging. Lesions were manually identified and reviewed using high-resolution T1 images, and additional associated stroke damage surrounding the lesion on the T2-FLAIR (‘lesionPLUS’). To assess CBF within regions surrounding lesion or lesionPLUS areas, lesions will be dilated in 3mm increments of adjacent rings. Individual grey matter only and grey plus white matter masks will be overlaid and mean CBF values from the left and right hemispheres will be extracted. Comparison of mean CBF between healthy controls and participants and mean CBF across hemispheres within participants will be conducted. Multiple linear regression analysis will be conducted to assess whether behavioural performance (spontaneous speech, naming and comprehension measures) are related to mean CBF values within the regions surrounding damage caused by the stroke beyond the lesion itself. The results from this study can potentially demonstrate how altered post-stroke perfusion influences language recovery. Additionally, it may inform functional neuroimaging studies regarding absence of activations in peri-damaged regions post-stroke.

Topic Areas: Disorders: Acquired; Language Production

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Investigating the functional relevance of cortical key nodes for action picture naming *Sandbox Series*

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Previous neuroimaging and neurostimulation work suggests that the left ventral premotor cortex (vPMC) and the left intraparietal sulcus (IPS) play key roles in action understanding, particularly in relation to tool and object use in action words. However, their roles in intransitive actions (i.e. actions that do not involve objects) are less clear. In an experiment employing Transcranial Magnetic Stimulation (TMS), we explore the involvement of two cortical regions in intransitive action picture naming. In this experiment, twenty participants named intransitive action pictures (e.g. LAUGH), accompanied by repetitive TMS to the left vPMC, left IPS, and right superior parietal lobe (SPL; acting as control site). TMS was applied at 10Hz for 400ms, starting simultaneously with picture presentation. Within each session, ten intransitive pictures were presented 40 times each (400 trials per session, 200 for active TMS and 200 for sham). Three sessions were conducted on separate days, one per targeted region (vPMC, IPS, SPL). We expected that TMS applied to the vPMC would lead to delayed naming times of intransitive action pictures, but IPS stimulation would produce no effect on naming latencies. This study is still undergoing data acquisition (currently 95% complete), but full results will be presented at the 2021 meeting of the Society for the Neurobiology of Language. This research is expected to further our understanding of whether these regions are involved in the production of action words and the organisation of action meaning, with potential suggestions for what mechanisms might be operating in these regions.

Topic Areas: Language Production; Meaning: Lexical Semantics

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Different time-course of activating tonal alternations in the production of Mandarin Tone 3 sandhi words: Evidence from reaction time survival analysis *Sandbox Series*

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Phonological entities (e.g., segments or lexical tones) may exhibit systematic changes conditioned by the phonological context. However, existing speech production models do not sufficiently specify how different phonological variants are activated during speech production We report results of a study aiming to shed light on the time-course of the activation of underlying and surface representations for phonological tonal variants. Our empirical base is Mandarin Tone 3 sandhi, a phonological alternation whereby a low-dipping tone (underlying form) changes to a rising tone, which resembles the lexical Tone 2, in the surface form when followed by another third tone. Previous research using the picture-word interference paradigm and stimulus onset asynchrony (SOA) manipulation suggests that both underlying and surface representations (Tone 3 and a Tone 2-like T3 sandhi variant) are activated but with different time course during sandhi word production (Nixon et al., 2015). This study thus aims to conceptually replicate the findings of Nixon et al. (2015), and to gain further insight into the time-course of activation via novel survival analysis (Reingold & Sheridan, 2014). Twenty-five native Standard Mandarin speakers were asked to produce disyllabic target Tone 3 sandhi words (e.g., 雨伞, yu3san3, 'umbrella') upon seeing a picture while their speech onset latencies were recorded. Each picture was preceded by a visual distractor, presented simultaneously with its spoken form auditorily. The distractor consisted of four types: a T3 identical-morpheme distractor (the same character as in the target word, e.g., 雨 yu3), a Tone 3 hetero-morpheme distractor (a different character sharing the underlying tone 3, e.g., 语 yu3), a Tone 2 distractor (a different character sharing the surface tone 2, e.g., 鱼 yu2), and a control distractor (a different character carrying either Tone 1 or Tone 4 with no tonal overlap, e.g., 预 yu4). Our results showed that both the Tone 3 and Tone 2 distractors yielded significantly shorter speech onset latencies than the control distractor, suggesting the activation of both tonal variants in production. Survival analysis on RT distributions revealed an earlier facilitatory effect of the Tone 3 distractors (321ms and 457 ms for the T3 identical- and hetero-morpheme distractor respectively) than the Tone 2 distractor (521 ms), confirming the different time course of the activation of the two tonal variants (Nixon et al., 2015). Furthermore, the latency differences between the T3 identical- and hetero-morpheme distractors revealed a significant effect of morphological identity. Further exploratory analysis suggests possible interactions of the effect of the distractors with the targets' lexical familiarity and entropy of the first character. Our results offer important insights into the time course and factors that condition the encoding of phonological alternations during speech production.
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Topic Areas: Language Production; Prosody

Slide Slam J8 Play Video

Differential effects of temporal and spectral modulation on onset and lexical tone recognition: Evidence from Mandarin Chinese *Sandbox Series*

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Various hypotheses have been proposed to explain the neural mechanism subserving hemispheric asymmetry in speech processing, including functional and acoustic accounts (Zatorre & Gandour, 2008). Among the acoustic accounts, the spectrotemporal modulation model (Flinker et al., 2019) computationally unifies concepts proposed by existing acoustic models and is found to be more compatible with the decomposition pattern of sounds by auditory neurons. The model postulates that temporal and spectral features differentially affect speech perception and explains the asymmetry in speech processing by proposing that auditory neurons in the left and right hemispheres are sensitive to different ranges of temporal and spectral information respectively. While several studies have confirmed the fragility of speech comprehension under temporal degradation and its relative robustness under spectral degradation (Flinker et al., 2019; Albouy et al., 2020) in non-tonal languages, it has not been examined before whether temporal and spectral degradation would have differential effects on the perception of different types of phonemes. For example, it is likely that lexical tones, which differentiate word meanings with systematic pitch differences, are more susceptible to spectral degradation. Mandarin Chinese, a tonal language, is thus particularly suitable to test this hypothesis and further advance our understanding of the impact of spectrotemporal modulation on speech intelligibility. We created a total of 120 meaningless Mandarin sentences, which were recorded from a native male Mandarin speaker, and filtered in the temporal and spectral domain respectively with six modulation cutoff values. For temporal modulations, the sentences were also filtered with the highest cutoff value in the spectral domain and kept constant across the six temporal modulation rates; the same was true for spectral modulations. Twelve right-handed native Mandarin speakers participated in the experiment. The filtered sentences were presented diotically to the participants in a random order, and the task was to write down the Chinese characters or homophones upon hearing each sentence. The accuracy of onset, rime and tone recognition was calculated separately for each sentence. Preliminary data showed that temporal degradation impaired onset accuracy more than rime accuracy and tone accuracy, whereas spectral degradation affected tone accuracy more than the other two, as predicted. The trend of rime accuracy fell in between onset and tone accuracy and did not exhibit a clear pattern. The preliminary results confirmed the hypothesis that temporal and spectral modulation differentially affects the perception of onsets and lexical tones. These findings have implications for understanding the relative role of temporal and spectral modulation in speech intelligibility in diverse language contexts with distinct prosodic characteristics. We plan to examine the hemispheric laterality for temporal and spectral processing in onset, rime and lexical tone perception in a dichotic listening paradigm in a second study. References A. Flinker, W. K. Doyle, A. D. Mehta, O. Devinsky, D. Poeppel, Nat Hum Behav. 3, 393-405 (2019). P. Albouy, L. Benjamin, B. Morillon, R. J. Zatorre, Sci New York N Y. 367, 1043-1047 (2020). R. J. Zatorre, J. T. Gandour, Philosophical Transactions Royal Soc B Biological Sci. 363, 1087-1104 (2007).

Topic Areas: Perception: Auditory; Speech Perception

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Neural Correlates of Learning Nominal Classification Rules: an fMRI study *Sandbox Series*

Diego Dardon[1], Hyeonjeong Jeong[1], Haining Cui[1], Ryo Ishibashi[1], Motoaki Sugiura[1]; [1]Tohoku University

Learning a second language requires not just learning abstract grammatical rules, but rules that rely on language-specific conceptual information. However, previous studies have explored the learning of abstract grammar rules, and there are little studies investigating the diverse set of grammar rules that rely on conceptual knowledge. Previous studies on adult second language learning reported that during the learning abstract grammar rules engaged the left inferior frontal gyrus and left ventral premotor cortex (Kepinska, de Rover, Caspers, & Schiller, 2017; Opitz & Friederici, 2003; Opitz & Friederici, 2004). In this study, we investigate the neural correlates during the learning process of nominal classification rules, grammatical systems with language particular ways of conceptualizing the natural world into categories such as liquids or plants (Kemmerer, 2014). Participants were 37 healthy, right-handed Japanese native speakers (Age 18-24, 17 females). We created a semi-artificial language based on Luganda that consisted of 72 concrete nouns with the nouns borrowed from Japanese to control for vocabulary learning and target the learning of the grammatical rules. The target grammar rule being noun class agreement between a noun and a demonstrative with each noun class taking a unique demonstrative. The noun classes divided semantically as: animate (i.e., dog), small inanimate (i.e., pen), and large inanimate (i.e., train). These semantic divisions are common for noun classes typologically (Aikhenvald, 2000). Participants learned the semi-artificial language over 3 learning phases (time 1, time 2, time 3). fMRI Scanning took place during the learning phases. During the learning phase, participants listened to 18 randomized correct noun-demonstrative combinations (learning condition) with each noun-demonstrative combination including a picture of the noun to prevent ambiguity. In addition, they heard the same 18 noun-demonstrative combinations but with the sound in reverse and a mosaic picture (control condition). After each learning phase, participants performed an offline grammatical judgment task that acted as a behavioral indicator of learning. The learning phases combined took approximately 14 minutes and the test phases combined took approximately 9 minutes for a total experiment time of 21 minutes. A one-way repeated measures ANOVA was conducted for behavioral results to compare offline test scores across the three time periods. There was a significant effect for time, Wilks' Lambda = .32, $F(2,35) = 36.72$, $p < .001$, multivariate partial eta squared = .67. These results that scores increased over time indicating learning took place. For fMRI analysis, the contrast of interest will be the Condition (learning vs control) X Time (time 1 vs time 3) interaction to find activation involved in learning nominal classification rules. In contrast to previous studies, we predict activation in the brain areas involved in conceptual and semantic knowledge, particularly the left anterior temporal lobes and left angular gyrus in addition to the areas related to the language network such as the left inferior frontal gyrus. We hope the findings contribute to the further understanding of the learning process in real-time with regards to the interaction between conceptual knowledge and grammatical structure.

Topic Areas: Morphology; Meaning: Combinatorial Semantics

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What are the sources of predictability and plausibility? A neurophysiological study of sentence comprehension in Korean *Sandbox Series*

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Predictability and plausibility based on semantic context are two critical features that determine how a word is processed and utilized to construct a message-level representation of a sentence. In previous ERP studies, the two factors have generally been associated with two patterns of biphasic negativity-late positivity: an N400-frontal positivity (fPNP) for unexpected but plausible sentence continuations and an N400-posterior positivity (pPNP) for unexpected and implausible continuations (DeLong, Quante, & Kutas, 2014; Kuperberg, Brothers, & Wlotko, 2020; Van Petten & Luka, 2012). This suggests that there are distinct ERP responses to conflicts, either induced by prediction (i.e., via the N400) or plausibility (i.e., via the divergence in the late positivity distribution). However, the question of whether different sentence constituents (e.g., argument nouns, modifiers, verbs) vary in their vulnerability to these conflict-prone processing features has remained unsolved. Thus, the present ERP study is designed to answer this question by comparing ERP responses to conflicts induced by two different verb-containing constructions (i.e., noun argument-verb vs. adverb modifier-verb) in Korean sentences. Taking advantage of the verb-final word order in Korean, nouns and adverbs preceding the shared sentence-final verb are separately manipulated to generate either a prediction or plausibility violation when combined with the verb. Thus, with the manipulation of three factors (i.e., constituent construction, expectancy, and plausibility), a total of five experimental conditions can be developed: 1) Control [CON] (e.g., 'Mary-nun (Mary-NOM) – elyewun (difficult-Adj) – sihem-ul (exam-ACC) swuepsi (numerously-Adv) – chiluko (take-V) …' which means 'Mary took the difficult test numerously and …'), 2) Adverb-verb unexpected congruent [A-UCNG] – replaces 'swuepsi (numerously-Adv)' with 'pwuncwuhakey (busily-Adv)'), 3) Adverb-verb (unexpected) anomalous [A-ANM] – replaces 'swuepsi (numerously-Adv)' with 'mwulkkulemi (blankly-Adv)'), 4) Noun-verb unexpected congruent [N-UCNG] – replaces 'sihem-ul (exam-ACC)' with 'swuswulel (surgery-ACC)', and 5) Noun-verb anomalous [N-ANM] – replaces 'sihem-ul (exam-ACC)' with 'mwunceylul (problem-ACC). The switched nouns and adverbs in all unexpected sentences lead the reader to predict a verb different from the one actually encountered, producing a conflict. High contextual constraint confirmed by high cloze probabilities and (in)congruency validation through plausibility ratings will be obtained and matched between conditions before the ERP experiment. The experimental procedure will consist of a segment-by-segment presentation (SOA = 800ms), and an acceptability judgement task to maximize participants' sensitivity to anomalies. Following the notion of N400 reduction reflecting processing benefits from previous semantic context, all four unexpected conditions are predicted to produce large N400 amplitudes. Within the unexpected conditions, there are two possible outcomes. In contrast to the noun-verb construction conflicts that are expected to yield significant negativity-positivity patterns, the adverb-verb conflicts may yield smaller, or even no late positive components. Such results would imply the more significant role of the mandatory argument-verb relation information (e.g., selectional restriction) – relative to the optional modifiers - in message-level representation development of a sentence and judgement of its overall plausibility. Alternatively, if the ERP responses to adverb-verb and noun-verb structures are comparable, it can be suggested that the construction of sentence meaning is not differentially affected by the two constructions.

Topic Areas: Meaning: Discourse and Pragmatics; Syntax

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Masked translation priming with or without translation equivalents: ERP evidence from Korean-English bilinguals *Sandbox Series*

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Numerous behavioral and neurophysiological studies have consistently found robust masked translation priming in the forward direction (e.g., Gollan et al., 1997; Hoshino et al., 2010; Midgley et al., 2009; Schoonbaert et al., 2009), in turn demonstrating how bilingual word recognition and underlying lexical organizations are distinct from that of monolinguals. Crucially, however, most studies have used translation equivalents as prime-target pairs, which makes it difficult to pinpoint the locus of the observed priming effects. Nearly full semantic overlap between prime-target pairs may ensure priming even in the absence of mandatory translation; however, whether robust masked translation priming is possible without semantic mediation remains unclear. To examine whether L1-to-L2 translation is an automatic process in bilinguals, the present study investigates the presence of masked priming that is obtainable only if translation takes place automatically and rapidly. Thus, we manipulated the relationship between prime-target pairs as follows. Relative to an identical L1 prime (e.g., 얼굴 /elkwul/ “face”), L2 targets were its translation equivalent (ID; face) or phonologically overlapped with its translation to varying degrees: moderate (MOD; fake), minimal (MIN; fool) or unrelated (CON; lime). Highly proficient late Korean-English bilinguals performed a masked priming lexical decision task (prime duration: 48ms) on 524 critical targets (131 per condition). Provided subliminal presentation of an L1 prime is subject to fast and automatic translation robust enough to produce priming without mediation via the semantic level, varying degrees of phonological overlap between prime-target pairs may differentially affect behavioral and ERP responses to target words. In lexical decision latencies, while facilitation should be observed for ID in comparison to CON, inhibition for phonologically overlapped targets (MOD and MIN) is expected in line with the Interactive Activation framework, analogous to competition between within-language form distractors and related targets (Guo et al., 2012). Although a preliminary behavioral study with eight participants did not reveal any statistically significant difference between CON and the critical conditions, a trend that is consistent with the predictions was observed with a 24ms facilitation for ID, and a 20ms and 4ms inhibition for MOD and MIN, respectively. To assess the nature of this behavioral trend, ERP responses will be simultaneously obtained. Lateral inhibition at the lexical level will translate to greater N400 negativity for MOD compared to MIN targets, which in turn should be more negative than CON, while the negativity for ID targets should be significantly reduced. If lexical activation spreads top-down to the sublexical level, differential modulation of the N250 component reflecting sublexical-to-lexical mapping (Grainger et al., 2006) is expected across conditions. Critically, N250 negativity should be smaller for MOD compared to MIN targets, reflecting a greater ease in sublexical-to-lexical mapping of targets due to preactivation of overlapping sublexical representations constituting the prime’s translation. Whether the behavioral results translate to modulations of ERP responses reflecting sublexical and lexical processing of L2 targets will be discussed as evidence that contributes to our understanding of processes involved in bilingual word recognition.

Topic Areas: Multilingualism; Reading

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Testing Bilinguals for the Known-Word Facilitation Effect in Speech Segmentation *Sandbox Series*

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Introduction: It has been well documented that word knowledge contributes to the segmentation of continuous speech (e.g., McClelland & Elman, 1986; Norris, 1994). Speech segmentation models (i.e., Brent, 1999) demonstrate that identification of known words within a speech stream allows the edges of adjacent new words to be inferred by listeners, thus presenting a means by which new words can be learned without formal instruction about those words. This language learning strategy has been shown to operate in both in adults (Dahan & Brent, 1999; White, Melhorn, & Mattys, 2010) and infants (Bortfeld, et al., 2005; Sandoval & Gómez, 2016). Thus, the nature of the interaction between word knowledge and auditory cues in the incoming signal is the basis of substantial research (see Mattys & Bortfeld, 2016). Recent research pitting top-down (i.e., lexical knowledge) against bottom-up (i.e., statistical cues in the signal) effects demonstrated that prior word knowledge can boost the effect of statistical cues in adult English monolinguals (Palmer et al., 2019). Thus, a known-word facilitation effect aids segmentation of novel artificial speech (see also Poulin-Charronnat et al., 2017). Here, we consider whether bilingual listeners show the same effect. Methods: In the current study, we compared performance by English monolingual ($n = 20$) and Spanish-English bilingual ($n = 22$) college students on an artificial speech stream segmentation task. We first documented detailed language background information for all participants. Half of the participants from each language group were familiarized with either a control stream made entirely of novel words (e.g., golatu, pigola, etc.) or a test stream, i.e., the same stream containing occasional instances of a known English word (i.e., “philosophy”). Following the familiarization phase, all participants were tested on their ability to recognize the novel words via a two-alternative forced choice task. In addition to the novel words (strings with 1.00 transitional probabilities across three CV syllables), the recognition task included part-words (i.e., strings straddling portions of novel words) and non-words (i.e., strings not present in the familiarization stream). Results: Using linear mixed-effects modeling, preliminary findings demonstrate that, when collapsing across both monolingual and bilingual groups, participants recognized significantly more novel words ($p = .022$) from the test stream ($M = .75$) than from the control stream ($M = .61$). This known-word facilitation effect was evident in the monolingual group ($p = .009$) but did not reach significance in the bilingual group ($p = .19$). Bilingual speakers performed significantly worse overall than monolingual speakers ($p = .005$; Monolinguals: $M = .75$; Bilinguals: $M = .63$). Conclusion: These results confirm the finding that the presence of known words in an otherwise novel and continuous speech stream boosts statistical learning. The reason for the discrepancy between monolinguals and bilinguals remains unclear, but it suggests that language experience affects the utilization of top-down lexical knowledge during artificial speech segmentation. Additional research is needed to delineate the factors and neural mechanisms contributing to the difference between monolinguals and bilinguals in how top-down information impacts performance on artificial speech stream segmentation.

Topic Areas: Speech Perception; Multilingualism

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Is there magnocellular facilitation in early visual word recognition? Evidence from ERPs *Sandbox Series*

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An influential theory in the field of visual object recognition proposes that fast magnocellular (M) information facilitates processing of spatially more fine-grained but slower parvocellular (P) information. While visual words can be considered to be a special type of visual objects, it is unknown whether magnocellular facilitation also plays a role in reading. We used a masked-priming experiment that has been shown to result in neural facilitation and tested whether these facilitation effects were mediated by the magnocellular system. In two experiments, the influence of magnocellular and parvocellular systems on visual word recognition was measured by contrasting the influence of either high vs. low spatial frequency primes (exp. 1) or luminance vs. color contrast primes (exp. 2). In each experiment, we presented unchanged primes in addition to M- and P-biased primes to measure basic neural facilitation. We replicated typical repetition effects in the N1, N250 and N400 components of the ERP with unchanged primes in both experiments. In exp. 1, we obtained repetition effects only in the N1 for both M- and P-biased primes. In exp. 2, the repetition effects were found in both N1 and N250 for both M- and P - biased primes. However, no interaction between prime type (M-biased vs. P-biased) and repetition was found, indicating that both M- and P- biased information together contribute to early visual word recognition.

Topic Areas: Reading; Meaning: Lexical Semantics

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An fMRI Localizer for American Sign Language Comprehension *Sandbox Series*

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When testing hypotheses about the functional activation of neural regions via fMRI, researchers commonly contrast a task involving the cognitive process of interest with a control 'localizer' task to isolate neural activity unique to that cognitive process. Localizer tasks are commonly designed on a per-experiment basis, but consequently results cannot be directly compared across studies. A solution is to create a standardized localizer task known to reliably activate neural areas associated with a particular cognitive process; however, because the language network is quite distributed and heterogeneous, traditional localization methods have not been successful. Fedorenko et al. (2010, 2011) designed a robust language localizer task using group-constrained subject-specific functional regions of interest which was able to elicit activation patterns specific to high-level spoken language processing (see also Scott et al., 2017). We designed localizer tasks for American Sign Language (ASL) to elicit linguistic processing at the lexical, syntactic, and discourse levels, contrasted with degraded (blurred) versions of the same stimuli acting as a baseline condition. The subject views a series of 17-second video clips in three conditions (lexical, syntactic, narrative) and presses a button between video clips to help maintain attention. The lexical condition consists of lists of nouns and verbs, which also allow us to contrast activation patterns for comprehending each class of words. The syntactic condition includes the same words as in the lexical condition, which are rearranged into complete, unrelated sentences. By matching the words across lexical and syntactic conditions, we will be able to contrast the two conditions and isolate activity related to syntactic processing over and above lexical retrieval. The narrative condition consists of excerpts from a story (Alice in Wonderland) with narrative prosody, character facial expressions, and use of dialogue and classifier constructions, as is typical of ASL storytelling. We predict that contrasting the three language conditions with the baseline condition will reveal activation in supramodal frontotemporal language areas. We also predict that contrasts between lexical, syntactic, and narrative conditions will increasingly activate bilateral parietal areas such as the supramarginal gyrus and superior parietal lobule, which have been previously associated with processing "spatial syntax" and classifier constructions, features unique to sign languages. Pilot data with one deaf signer, in which two scanning sessions were conducted one month apart, demonstrated consistent and robust activation across localizer conditions in frontotemporal and parietal language areas. These localizers will enable us to a) isolate functional regions of interest (fROIs) for lexical, syntactic, and narrative levels of ASL processing, b) examine patterns of inter-subject variation, and c) assess whether fROIs are activated in domain-specific or domain-general ways.

Topic Areas: Signed Language and Gesture; Methods

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Neural cortical measures are associated with auditory improvement after cochlear implantation in young children with congenital hearing loss *Sandbox Series*

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Auditory and spoken language outcome after cochlear implantation, the most effective treatment available for children with congenital profound bilateral sensorineural hearing loss, is quite variable even in early implanted children (Niparko et al 2010). There is great need to identify objective markers associated with outcome after implantation. Doing so would enable forecasting of individual risk for language development far below normal hearing children, providing an opportunity to develop customized treatment to improve outcome. Previous studies have shown the impact of auditory deprivation on brain regions involved in hearing, speech and language (Ratnanather et al 2020). Our previous studies (Feng et al 2018) have shown that gray matter density in preserved, not damaged, neural regions are more predictive to the language outcome measured 6 month after the implantation. In this study, we further validated our work using an external cohort to investigate whether the neural-based features are more predictive of the implantation outcome compared to non-neural characteristics, and whether the auditory regions or non-impaired neural regions are correlated with post-implantation outcome. A set of young children (mean age at implantation was 27.5-month-old) with congenital hearing loss was recruited in Hong Kong. The whole-brain MRI 3D T1-weighted images were obtained before implantation. The pre- and 6-month post-implantation auditory ability was measured by LittlEARS, validated to assess early auditory development in children with cochlear implantation (Obrycka et al 2017). The imaging data was processed with Infant Freesurfer (Zöllei et al 2020). The cortical thickness, a heritable and plastic measure sensitive to cognitive abilities and pathologies (Dickerson et al 2008; Shiohama et al 2019), was extracted from each individual subject and mapped to a standard space via surface registration. Two sets of regression analyses were conducted. The first was to test whether the implantation age was correlated with the baseline auditory outcome and 6-month-post-implantation auditory improvement (post-pre). The second set of analyses was to conduct vertex-based regression analyses between the cortical thickness and baseline and 6-month improvement of auditory outcomes while controlling the implantation age. The surface-based statistical results were corrected for multiple comparisons using Monte-Carlo simulation. Statistical results showed that the implantation age was not correlated with the baseline and improvement of auditory outcomes. Surface-based regression results showed that no significant clusters were correlated with baseline auditory outcome. The regression analysis between imaging and the auditory improvement showed that cortical thickness in left supramarginal, superior, middle and inferior temporal cortices, and right cuneus was significantly negatively correlated (corrected $p<0.05$) with the 6-month auditory improvement measured by LittlEARS. The findings suggest that, rather than age, neural cortical features in hearing loss children are correlated with the auditory improvement after implantation, indicating the superior of using neural measures (compared to non-neural characteristics) for the prediction of later auditory outcome. Moreover, not only the primary auditory regions, shown to be damaged in hearing loss children, but also secondary and associated cortices are correlated with auditory improvement, indicating the role of cortical re-organization in auditory improvement after cochlear implantation.

Topic Areas: Perception: Auditory; Disorders: Developmental

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Cortical tracking of speech envelope and phonetic information in children with cochlear implants and hearing children. *Sandbox Series*

Tatiana Matyushkina[1], Sharon Coffey-Corina[1], Lee Miller[1], David Corina[1]; [1]UC Davis Center for Mind and Brain

Cochlear implantation for the treatment of congenital deafness has been highly successful, however the outcomes for speech perception remain highly variable (Tobey et al 2012). A long-standing issue in the field has been how best to assess the quality and content of speech percepts that children with cochlear implants experience and how the nature of the signal may change under conditions of multi-modal (auditory and visual) stimulation. We are using predictive modeling to quantify the relationship between features of speech stream and the EEG signal. We make use of a novel electrophysiological paradigm (Backer et al. 2020) to obtain EEG data during children's perception of continuous speech with interposed visual stimulation. In the study the participants (CI N = 7, mean age 6y, mean age of implantation 17m; hearing control N = 7 (mean age 6y 5m)) were instructed to watch a silent cartoon presented in the middle on the screen. Around the cartoon two concentric checkered rings in the background flickering at different frequencies (7.5 and 12 Hz). Auditory stimuli consisted of 49 unique sentences (sampled at 22,050 Hz) from the Harvard/IEEE Corpus (IEEE 1969) that were concatenated into a 2-minute long WAV file of continuous speech. Periods of ambient speech occurred in the presence and absence of the visual flicker stimulation. The EEG data then were filtered between 1 and 15 Hz and ICA was performed to remove ocular and CI-induced artifacts. After that we used mTRF toolbox (Crosse et al., 2015) to create encoding models. The mTRF method involves fitting a temporal response function that describes a mapping between features of sensory stimulus like speech envelope and the EEG signal (Di Liberto et al., 2015). Using this method, we hope to compare cortical tracking of a low-level speech feature (envelope) as well as phonetic information (such as manner of articulation, place of articulation etc.) in the presence of distracting visual stimuli in hearing and CI children. To the best of our knowledge this method has not been applied to pediatric populations with cochlear implants. Preliminary data analysis has shown higher correlation scores between reconstructed and original envelope in CI group compared to hearing group ($r = 0.16$, $p < .0001$ for CI group, $r = 0.09$, $p < .0001$ for hearing group). This might reflect better envelope tracking in CI group as it has been shown that individuals with hearing impairments show enhanced envelope tracking when compared to hearing counterparts (Decruy et al., 2020). Previous studies have shown lower phoneme discrimination accuracy in CI children (Bouton et al. 2012), thus we predict to see worse performance of our phonetic feature model in CI children than in hearing children. This may indicate that children with CI rely more on the broader context and less on the phonetic features during speech recognition.

Topic Areas: Speech Perception; Development

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Reading demands modulate brain responses to word frequency: an fMRI study

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Word frequency plays an important role in lexical processing. More frequent words are processed more efficiently than low frequency words, which has been typically inferred from the fact that less frequent words generate higher response latencies in diverse linguistic behavioural tasks (Brysbaert et al., 2018). At the neural level, a few functional MRI (fMRI) studies have found an increase of activation for low frequency words as compared to high frequency words in the inferior frontal gyrus (IFG), as well as in the ventral occipito-temporal cortex (vOTC) (Carreiras et al., 2006; Fiebach et al., 2002; Graves et al., 2007; Kronbichler et al., 2004). Here we investigate whether this word frequency effect (WFE) is modulated by reading demands, a factor that has been found to modulate reading-related activation in these brain regions (Dehaene & Cohen, 2011; Schuster et al., 2015). To this end, 56 healthy participants underwent MRI scanning while they performed two versions of a single word reading task: a perceptual low-level task and a semantic high-level task. In both versions, subjects were presented with high and low frequency words, pseudowords and consonant strings. In the perceptual reading task, they were asked to press a button any time they saw a coloured letter within the string. In the semantic version, they were instructed to press a button whenever they saw the name of an animal. Region-of-interest (ROI) analyses were performed, defining six left-lateralised areas: inferior frontal gyrus (IFG) pars orbitalis, IFG pars triangularis, IFG pars opercularis, medial-superior temporal gyrus (MTG/STG), ventral occipito-temporal cortex (vOTC) and inferior parietal cortex (IPC). We found a significant task by frequency interaction in IFG pars orbitalis and pars triangularis. Low frequency words showed higher regional activation only in the semantic task. Although in pars opercularis increase of activation was observed for less versus more frequent words only in the semantic task, the task by frequency interaction was not significant in this region. We found no effect of frequency in vOTC, although this region showed significantly higher activation in the semantic than in the perceptual task. Functional connectivity analyses revealed differences as a function of the ventral versus dorsal reading networks for the WFE. Our results partially support previous findings on the WFE in terms of brain activation. Also, our findings emphasize the role of the ventral reading network in the WFE. These findings have potential implications on the theories regarding lexical and pre-lexical processing.

Topic Areas: Reading; Meaning: Lexical Semantics

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Extending the reading network: thalamo-cortical connectivity during audio-visual letter-speech sound processing in children with and without developmental dyslexia

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Over the last decades, neuroimaging research has established reduced cortical activation in key brain areas for speech and text processing in dyslexic compared to typical readers. While most of this research has focused on cortical activation and connectivity, much less is known about the contribution of subcortical structures to the reported difficulties in speech and text processing. In this project, we aim to explore functional bilateral thalamo-cortical connectivity patterns in 8-10 year-old children with and without dyslexia using an audio-visual text-speech perception paradigm. Here, children are simultaneously exposed to audio-visual letter-speech sound and meaningless symbol-speech sound pairs in a passive viewing task. We will extract the activity time courses of the bilateral thalami and cortical reading network in response to these audio-visual stimuli and perform a psychophysical interaction (PPI) analysis. Preliminary results indicate differences in connectivity patterns between groups: while dyslexic readers show bilateral thalamo-cortical connectivity, typical readers display a more left-lateralized connectivity pattern in both thalami. A next planned step is to explore potential links between these functional connectivity differences and children’s reading (-related) skills.

Topic Areas: Reading; Perception: Speech Perception and Audiovisual Integration

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Periodic Eye Movements During Reading—of Words and Chunks?

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Current auditory neuroscience emphasizes the role of neural oscillations for speech tracking (Poeppel & Teng, 2020). Recently, the complimentary role of intrinsic rhythms in internal linguistic processing has entered focus (Meyer et al., 2020). If indeed intrinsic rhythms are critical to linguistic processing, they should also emerge for input that does not contain any rhythmic structure, which might otherwise disguise intrinsic activity. One good modality to study this is reading—words occur in space without imposing a specific tracking rate on the reader. Eye movements are guided by linguistic knowledge in combination with attention and oculomotor constraints (Kliegl et al., 2006). Rhythmic eye movements during reading might provide insight into the degree to which internal linguistic processing exhibits intrinsic rhythms, and the extent to which there are specific intrinsic rates regulating different internally generated linguistic units (e.g., words versus phrases). We analyzed the Ghent Eye-Tracking Corpus (Cop et al., 2017) of eye-tracking data from 14 participants during naturalistic reading of a novel. In a first step, we analyzed the power spectrum of saccade onset times. In line with previous research (Gagl et al., 2019), we hypothesized periodicity in the theta-band range (i.e., 4–8 Hz), previously linked to attentional cycles in vision and syllabic tracking in audition (e.g., VanRullen, 2018). Power spectra were calculated and tested against surrogates to establish above-chance saccade rates; spectral variance was used as effect size. We replicated previous observations of a 4–5-Hz rhythm, confirming that saccadic information uptake during reading is rhythmic. In a second step, we tested for larger temporal units, consistent with a proposed role of delta-band oscillations (i.e., 0.5–4 Hz) in linguistic chunking (e.g., Henke & Meyer, 2021). Inspired by previously reported wrap-up effects at the end of clauses and sentences (Tiffin-Richards & Schroeder, 2018), we hypothesized that processing should slow down at the end of larger temporal units. To test for periodic fixation slowdowns, we computed a time series of differences between fixation durations for subsequent words—effectively highlighting slowdowns from word to word. Comparison of fixation duration spectra with surrogates indicated a prominent peak in the delta band (i.e., < 1 Hz), suggesting that fixations indeed slow down in a periodic fashion at a frequency within the delta band. Together, these results show that eye movements during naturalistic reading contain hierarchical rhythmic structure akin to neural oscillations during speech tracking. Moreover, this rhythmicity appears to be intrinsic rather than externally imposed. We suggest that the saccadic rhythm may reflect cycles of optimal sensitivity for sampling new words, whereas fluctuations in fixation duration may index an intrinsic chunking mechanism that integrates words at a rate corresponding to larger linguistic units.

Topic Areas: Reading; Speech Perception

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Learning to write shapes literate speech perception

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Previous research suggest that literacy, specifically learning alphabetic letter-to-phoneme mappings, modifies online speech processing, and enhances brain responses to speech in auditory areas associated with phonological processing. However, alphabets are not the only orthographic systems in use in the world, and hundreds of millions of individuals speak languages that are not written using alphabets. In order to make claims that literacy per se has broad and general consequences for brain responses to speech, one must seek confirmatory evidence from non-alphabetic literacy. To this end, we conducted a longitudinal fMRI study in India probing the effect of literacy in Devanagari, an abugida, which encodes speech as consonant-vowel symbols, on functional connectivity and cerebral responses to speech in 91 variously literate Hindi-speaking individuals. Twenty-two completely illiterate participants underwent six months of reading and writing training, while two control groups, one literate (N=26) and one illiterate (N=12) underwent no training. All three groups returned for a follow-up scan after six months. We find that Devanagari literacy does not correlate with BOLD response to sentences at the whole brain level or in regions of interest selected a priori for their role in phonological processing, the planum temporale (PT) and posterior superior temporal gyrus (pSTG). At baseline there was evidence in favour of the null hypothesis of no relationship between literacy and auditory brain responses (N=91, correlation between word reading scores and BOLD: PT, Kendall's tau = .007, BF10 = 0.137; pSTG, Kendall's tau = -.030, BF10 = 0.149). After training, despite improvements in reading scores and letter recognition, there was evidence against increases in BOLD response to speech in either PT or pSTG (BF10s < 0.3). However, literacy is associated with increased functional connectivity between pSTG and dorsal sensorimotor cortex consistent with the Graphomotor Frontal Area (GMFA) during speech processing (Baseline, N=91, correlation between literacy and pSTG-GMFA connectivity significant a cluster-mass corrected p<.05, 604 voxels), which increased significantly after literacy training, in the trainee group only (Time*Group interaction: F(2,57) = 4.602, p = .015). Taken together, the results suggest that learning to read does not in and of itself alter brain response to speech, but that learning to map sounds onto written symbols potentially fosters phonological-graphomotor connections. We propose that neural orthography on speech processing effects must be considered with regard to the properties of the orthography at hand, in particular, the speech unit that is encoded in the characters - it is conceivable that learning to map subsyllabic segments to a visual code in alphabetic writing systems might require or induce modifications to auditory processing and representations of speech in order to support the phoneme-level manipulations and representations that are less relevant for a syllable based orthography. These findings show that a radical reconfiguration of the neurofunctional substrates of online speech processing is not a universal result of learning to read, and raise the possibility that writing, not only reading, may be instrumental in creating a functional scaffold that can modify literate speech perception.

Topic Areas: Reading; Speech Perception

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The representations of Chinese characters: evidence from sub-lexical components

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Little research has been done about the neural substrate of the sub-lexical level of Chinese word recognition. In particular, it is unclear how radicals participate in Chinese word processing. We compared two measures of radical combinability: position-general radical combinability (GRC) and position-specific radical combinability (SRC) depending on whether the left or right side of the radical is taken into account. We selected characters with embedded target radicals that had different GRC and SRC measures. These measures were used as predictors in a parametric modulation analysis and a multivariate representational similarity analysis (RSA). 41 native Mandarin speakers were asked to read words in search of animal words. Results showed that SRC is a better predictor than GRC in decoding the neural patterns. Whole-brain analysis indicated that SRC is encoded bilaterally in the inferior frontal gyrus (IFG, pars opercularis and pars triangularis), the middle frontal gyrus (MFG), and a region on the border of the superior parietal lobule and the inferior parietal lobule (SPL/IPL). ROI-based RSA further confirmed the results of the whole-brain analysis. Furthermore, we observed a correlation of another sub-lexical variable, logographeme composition, with bilateral activity in SPL. Logographemes refer to the basic stroke combinations that form radicals and characters. Finally, we observed consistent involvement of bilateral cerebellum activity in Chinese word recognition. Our findings confirm the importance of sub-lexical components (SRC and logographeme composition) in Chinese word recognition and also confirm that Chinese word recognition involves more bilateral processing than word recognition in alphabetical languages.

Topic Areas: Reading; Writing and Spelling

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The use of non-invasive brain stimulation techniques to improve reading difficulties in dyslexia: a systematic review

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Non-invasive brain stimulation (NIBS) allows to actively and non-invasively interfere with brain function. Across recent years, different NIBS protocols have been used to probe the causal relevance of specific brain regions for different language and reading-related tasks. Aside from inhibiting specific processes, NIBS may also be used to enhance cognitive functions. As such, facilitatory NIBS protocols have the potential to alleviate different symptoms and difficulties in various disordered populations, such as individuals with learning disorders. Such an approach may be particularly promising to support training of reading and writing skills in individuals with dyslexia. However, despite the growing interest in modulating learning abilities, a comprehensive, up-to-date review synthesizing NIBS studies with dyslexics from behavioral and neural viewpoints is missing. Here, we fill this gap and elucidate the potential of NIBS as treatment option in individuals with dyslexia in a systematic review. The findings of the 14 included intervention studies suggest that repeated sessions of reading training (e.g., spelling training) combined with different NIBS protocols may induce long-lasting improvements of reading performance in child and adult dyslexics, opening promising avenues for future research. In particular, the "classical" reading areas of the left hemisphere seem to be most successfully modulated through NIBS, and facilitatory NIBS protocols may improve various reading-related subprocesses (e.g., word, pseudoword or text reading). Investigating the causal relevance of specific brain regions for reading in dyslexics can help shed further light on the reading circuits and their contributions to particular reading-related tasks. Finally, we point out that future studies should combine NIBS with neuroimaging to increase our understanding of the neurobiological basis of NIBS-induced improvements in dyslexia, and explore short-term plasticity within the reading circuits.

Topic Areas: Reading; Writing and Spelling

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How and when are acoustic-phonetic predictions formed during silent reading?

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A well-established line of research demonstrates that human perception is shaped not only by sensory information from our environment, but also by our prior knowledge and expectations. For speech, numerous studies demonstrated that comprehension of perceptually degraded spoken words improves when they are primed with matching written text compared to mismatching text (Sohoglu et al, 2014, JEP:HPP). Behavioural and neural (fMRI, MEG) evidence suggests that this prior knowledge acts as a top-down prediction during speech perception (Davis & Sohoglu, 2020). Here we re-analyse a previously published dataset (Sohoglu & Davis, 2016, PNAS) to investigate the temporal dynamics of neural representations of written text and their transformation into acoustic-phonetic predictions. Participants were presented with 468 monosyllabic written then spoken word pairs. Each trial started with the presentation of a written word, followed by a matching, or mismatching spoken word at one of 3 levels of sensory detail. The amount of sensory detail in speech was controlled using noise vocoding (3, 6, 12 channels). After each word, participants rated the clarity of the spoken words on a four-point scale from unintelligible (1) to fully intelligible (4). We collected MEG recordings from 21 participants while they performed the task. In the present analysis we focused on the time window after the presentation of written words and before presentation of spoken words to investigate how acoustic-phonetic predictions are formed from written text. We used representational similarity analysis (RSA) to compare the representational structures in MEG recordings to hypothetical representational structures suggested by various computational models. Specifically, we used the Mahalanobis distance to calculate the dissimilarity between neural activity patterns across MEG channels for each pair of written words, separately for each timepoint. We also computed model representational structures across word items based on orthographic, acoustic, and phonetic features. These model representational structures are then correlated, timepoint-by-timepoint, to the similarity of observed neural representations. One plausible hypothesis would be that neural representations are more similar to orthographic representations early after the presentation of the written text, whereas acoustic and phonetic representations emerge later, prior to the presentation of the spoken word. Behavioural results demonstrated higher clarity ratings for spoken words which were preceded by matching compared to mismatching written text, replicating previous findings that prior knowledge contributes to speech perception. Effects of matching text were numerically equivalent to doubling the amount of sensory detail (vocoder channels). Preliminary MEG results show an above-chance correlation between the similarity of spatial patterns of neural activity and Levenshtein edit distance for specific pairs of words (i.e., orthographic representations) between 200 and 500 ms after written word onset. In depth analyses of other types of representations (i.e., acoustic, phonetic) are ongoing.

Topic Areas: Speech Perception; Reading

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Phonetic similarity facilitates long-distance, but not nested dependency processing in preschoolers: A mismatch response study

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Language comprehension typically involves successful tracking of distant speech units. Tracking of multiple, nested relations between these elements is computationally demanding and mastered only late during preschool years (Fengler, Meyer, & Friederici, 2016; Kidd & Bavin, 2002). While processing of distant relations is generally facilitated when dependent elements are linked by statistical probability and perceptual similarity (Sandoval & Gómez, 2013), this has not yet been explored for phonetic similarity in nested structures. To examine the effect of phonetic similarity on nested dependency processing, we recorded event-related brain responses (ERPs) to syllable sequences in preschoolers aged 2-4 years (n = 38). We employed a passive-listening oddball paradigm containing standard sequences with nested dependencies of the form [A1 [A2 C B2] B1], where each element Ai predicted element Bi. Dependencies were marked such that dependent syllables were phonetically similar (1-2 phonetic feature changes) in three different conditions, randomly presented in the stimulus stream: a) only the outer dependency b) only the inner dependency, or c) both dependencies were phonetically similar. Note that in all conditions, both inner and outer dependencies could be tracked by their repeated occurrence across the standard sequences, yet were additionally highlighted by phonetic similarity according to conditions a-c. For each standard sequence, deviant syllable sequences were included that violated the expected nested dependency by reversing the position of the two final syllables (element Bi). Differential ERP responses to these violations (i.e., mismatch responses) compared to standard sequences would indicate successful processing of the respective dependency. Results revealed positive mismatch responses to dependency violations corresponding to the respective phonetically marked outer dependency (condition a) or inner dependency (condition b) independently of age. Thus, despite both nested dependencies being violated in these sequences, children only showed responses to the phonetically marked ones. In contrast, for sequences where both inner and outer dependencies were marked by phonetic similarity (condition c), children revealed no mismatch responses. Together these findings draw a multifaceted picture of dependency processing during preschool years under passive-listening conditions. Phonetic similarity indeed supports the processing of distant elements, even enabling the processing of long-distance dependencies (spanning three inner elements) that are not tracked without additional marking (see condition b). Similarly, phonetic similarity also enables the processing of the acoustically less salient inner dependency (at non-edge positions) that is not detected without additional marking (see condition a). Yet, when both inner and outer relations are simultaneously phonetically marked, children do not process the nested dependency. Our findings thus mirror previous behavioral work (Fengler, Meyer, & Friederici, 2016; Kidd & Bavin, 2002) showing that only during later preschool years, children reliably process nested dependencies in sentences.

Topic Areas: Speech Perception; Syntax

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Compositional meaning influences the BOLD response in language critical cortex via interaction between LIFG and LMTG

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Left inferior frontal gyrus(LIFG)has been proposed to exhibit hub-like properties in various network contexts, often in the context of brain networks observed during language experiments(Hagoort,2014).Specifically,it has been claimed that LIFG facilitates the construction of combinatorial representations derived from linguistic input and known world-information via bi-directional interactions with other brain regions(Hagoort,2017). If so,then traces of this functionality should be observable in terms of LIFG related, brain-network BOLD activity, both via a top-down route which might target regions that respond more acutely to individual words,and via its own response to bottom-up signaling from these same regions.The combinatorial procedures underlying these dynamics are assumed to give rise to sentence-level meaning, which can’t be explained in terms of the lexical meanings of individual words.METHODS:To investigate this,we designed a priming experiment.Participants were asked to read well-formed sentences and scrambled versions of these sentences,in which the word order did not form a proper sentence.Sentences and their scrambled versions were followed by a target-word.Target-words related to the preceding text in one of four distinct manners.Targets could be(1)primed by the compositional meaning of a sentence,(2)primed by repetition of a single word that was embedded in a sentence,(3)primed by repetition of a single word embedded in a scramble,or(4)not primed at all by the preceding scramble.Repetition primes were expected to facilitate lexical access,but they were not expected to influence top-down information available to the core language network via signaling from LIFG. By including a manipulation whereby a repetition-prime was also embedded in a scramble,it was possible to dissociate repetition priming from compositional/repetition-priming effects.We were thus able to observe three modes of priming(1.compositional only,2.compositional with repetition,and 3.repetition only).This allowed us to test the prediction that LIFG generally facilitates unification in the linguistic domain with broadly contoured compositional information,beyond more specific phonological,semantic or syntactic combinatorial processes. A 3T fMRI experiment(n=19)was performed in which participants read prime/target pairs via word-by-word presentation while in the scanner.No experimentally relevant task was performed during the experiment.RESULTS:Group-level results showed a BOLD contrast in LIFG during the reading of a compositional-target compared with a sentence/repetition-target. This suggests that compositional information drove LIFG activity differently in the absence of repetition priming.Additional contrasts probing the response differences between primes and targets were also analyzed, and support the interpretation that sentence/compositional-targets are processed using the same network as used when reading the priming sentences.A subsequent gPPI connectivity analysis was performed using individualized LIFG ROIs based on the group contrast described above.The group level connectivity profile associated with this contrast revealed an interaction with left middle temporal gyrus.CONCLUSION:Together, the results provide evidence that sentence/repetition priming facilitated lexical access in LMTG by providing an additional means of priming beyond the compositional route.This resulted in reduced BOLD throughout language critical cortex,mediated by an interaction with LIFG. In contrast, sentence/compositional priming resulted in increased BOLD in similar brain regions,most prominently in LIFG. Interpreted in light of the gPPI result,we argue that dynamic connectivity of LIFG with LMTG during word reading contributes to establishing compositional representations,referring to sentence-level meaning beyond the lexical meanings of individual words.

Topic Areas: Meaning: Combinatorial Semantics; Reading

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Not in a bilingual mood: Reduced effects of mood on semantic integration in the non-native language

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Introduction: Neurophysiological research has pointed to a dampened sensitivity to negative stimuli in the non-native (L2) relative to the native language (L1) (e.g., Wu & Thierry, 2012; Jończyk et al., 2016). Interestingly, accumulating evidence concerning L1 processing has also revealed that semantic processes may be greatly influenced by one's mood – an unobtrusive, slowly-changing, and low-intensity affective background states (e.g., Chwilla et al., 2011). Yet, the role of positive and negative moods on language comprehension in the bilingual context has thus far received little scholarly attention. Therefore, the current event-related potential (ERP) study aimed to determine whether and how lab-induced positive and negative moods modulate semantic integration processes in Polish (L1) – English (L2) bilingual speakers when processing their L1 vs. L2. Methods: Eighteen high-proficient unbalanced late Polish–English bilinguals participated in the study (all females) and performed a semantic decision task to 180 emotionally neutral sentences in each language. Each sentence included a critical word in a mid-sentence position, semantically congruent or incongruent with their sentential contexts (e.g., These houses were transformed into country mansions/lobsters permanently, respectively). A positive and a negative mood were evoked via 14 affectively evocative, animated film clips in each mood condition. Electroencephalography was employed to continuously record participants' brain activity while reading the sentences in-between watching the film clips. Results: In the 600–800 ms time window, in the positive mood condition, we found an increased late positive complex (LPC) (i.e., a neural marker of semantic integration and re-analysis) response to meaningless compared to meaningful sentences, irrespective of the language of operation. In contrast, in the negative mood condition, we found an increased LPC response to L2 compared to L1 meaningful sentences, with no such a between-language difference for meaningless sentences. Discussion: The present study, therefore, offers novel evidence on bilingual language comprehension, revealing that L2 semantic integration may remain unaffected by potentially adverse effects of a negative mood. This is consistent with previous studies showing a decreased sensitivity to negative content in L2 (e.g., Jończyk et al., 2016). As proposed by Wu & Thierry (2012), this may relate to cognitive prevention, involuntarily activating a suppression mechanism upon encountering a potentially upsetting stimulus in L2, thereby inhibiting full spreading of activation through the semantic network. References: (1) Chwilla, D. J., Virgillito, D., & Vissers, C. Th. W. M. (2011). The Relationship of Language and Emotion: N400 Support for an Embodied View of Language Comprehension. Journal of Cognitive Neuroscience, 23(9), 2400–2414. (2) Jończyk, R., Boutonnet, B., Musiał, K., Hoemann, K., & Thierry, G. (2016). The bilingual brain turns a blind eye to negative statements in the second language. Cognitive, Affective, & Behavioral Neuroscience, 16(3), 527–540. (3) Wu, Y. J., & Thierry, G. (2012). How Reading in a Second Language Protects Your Heart. Journal of Neuroscience, 32(19), 6485–6489.

Topic Areas: Meaning: Lexical Semantics; Reading

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Brain responses to phonological well-formedness as revealed by fast periodic visual stimulation

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The current EEG study aimed at investigating whether phonological constraints are processed differently from lexical attestedness. We focused on the Sonority Sequencing Principle (SSP) and used the fast periodic visual stimulation paradigm. French native speakers (N = 24) were presented with streams of CCVC items (C: consonant, V: vowel). The items included pseudo-words with frequent CC clusters in French with rising sonority (e.g., dr) and non-words with unattested or very rare CC in French with either rising sonority (e.g., tl) or falling sonority (e.g., vp). The streams consisted in the presentation of four pseudo-words following the presentation of one non-word for 60 seconds. In one of the conditions, the non-words were the items with rising sonority CC (i.e., well-formed condition, WF). In the other condition, the non-words were those with falling sonority CC (i.e., ill-formed condition, IF). A previous behavioral study using the same items showed that French native speakers discriminate between unattested rising and unattested falling CC and are thus sensitive to both dimensions. In the present study, items were presented at a rate of 6 Hz. The frequency of non-words, which were inserted every 5 items, was therefore 1.2 Hz. EEGs were analyzed in the frequency domain. Based on prior studies, we expected to observe a peak at 6 Hz in both conditions. We also expected that non-words would elicit discrimination responses at 1.2 Hz rate (and its harmonics). If the processing of the SSP differs from that of lexical attestedness, we would observe a differential response in the IF condition compared to the WF condition. Analyses were performed on the electrodes showing maximal responses: the middle occipital electrode Oz for the base response at 6 Hz and the occipito-temporal electrodes PO7 and PO8 (and two surrounding electrodes) for the discrimination response at 1.2 Hz and its harmonics. As expected, a significant response was obtained at 6 Hz in both conditions, without any difference between conditions. A discrimination response at 1.2 Hz rate (and its harmonics) was observed in both conditions. Contrary to the WF condition, the discrimination response was right lateralized in the IF condition. This result suggests that the processing of phonological constraints, at least the SSP, may be different from the processing of lexical attestedness. Moreover, the fact that the differential activation was observed using the fast periodic visual stimulation paradigm suggests that early automatic mechanisms may be involved.

Topic Areas: Phonology and Phonological Working Memory; Reading

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Modeling the mental lexicon using a spiking neuron network for simulating speech tasks in case of different types of aphasias

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Introduction: Large-scale neural models allow to set up of a concrete architecture for all functional modules of speech processing and give a concrete temporal sequencing of neural activations occurring during speech production or speech perception tasks. These models allow us to develop a better understanding of the basic functioning of neural processes occurring in speech processing. Method: Our neurocomputational model is based on the NENGO.ai-approach. The model in its current version is capable of simulating word production tasks (e.g., picture naming), word comprehension tasks (e.g., finding a superordinate concept or generic term) as well as word repetition tasks. Different versions of the model have been implemented for modeling a normal speaker as well as six types of speakers suffering from different types of aphasias, i.e. Broca's, Wernicke's, transcortical motor, transcortical sensory, conduction and mixed or global aphasia. In case of each of the model variants about 20 different speakers were modelled, suffering from different degrees of neural dysfunctions representing the appropriate type of aphasia. All three types of tasks (production, perception, repetition) were applied to each of the model speakers and each model speaker performed 3 tasks each, leading to about 350 simulation runs. Results: By analyzing the task performance of all runs we were able to generate typical symptoms of aphasic speech. Performance rates decreased differently with increasing degree of neural dysfunction for the production, perception and repetition task in case of the different types of aphasia as predicted by natural data. Conclusions: The model gives new insights, how speech processing can be understood from a neuro-functional perspective because the neural model used here is neurobiologically plausible: (i) The model is based on a functional network of about 200000 spiking neurons (LIF neurons); (ii) the model uses neuron buffers containing neurobiologically plausible neural activation patterns for representing phonological, lemma or semantic forms; (iii) the model uses neurobiologically realistic associative memories in order to simulate transformations of neural activation patterns from concept via lemma to phonological form levels and vice versa; (iv) the model comprises an action control component (cortico-cortical control loop including a model of the basal ganglia and of the thalamus) for modeling a correct temporal sequencing of all peripheral and central actions needed to simulate a speech task. Thus, the neural architecture of the model and the temporal succession of neural activation patterns occurring within different parts of the model elucidate basic functional principles of the interaction of the mental lexicon (central knowledge repository) with different neuron buffers representing neural activation patterns at different levels of the production and perception pathway.

Topic Areas: Computational Approaches; Disorders: Acquired

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The (not that) simple-view of reading: The neurobiology of executive-function and dyslexia

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Purpose: In a series of studies including neuroimaging and behavioral/cognitive measurements, we aimed to define the involvement of executive-functions in reading and reading difficulties. Rational: The Simple view of reading model suggests that reading comprehension relies on both intact language and decoding abilities. However, recent updates to the model pointed at the important contribution of executive functions to intact reading. Approximately 10-15% of children in the western world have reading difficulties (RD or dyslexia), a neurodevelopmental disorder known to impact academic achievements as well as social and emotional wellbeing. Methods: Here, we aimed to study a)the role of executive functions in reading among children with RD and b) to examine the effect of an executive-functions-based computerized reading training on neural circuits supporting reading abilities and executive-functions in these children using a multimodal approach including several MRI methodologies as well as EEG data. Results highlight the role of executive functions in reading among children with RD: decreased event-related potentials evoked from an anatomical brain region related to executive functions [i.e. the anterior cingulate cortex (ACC)] and functional MRI data showed decreased functional connectivity of cognitive control networks related to this region (i.e. cingulo-opercular network). We then demonstrated the effect of this intervention on these functional connections during both reading and resting-state conditions with increased functional connectivity in the cingulo-opercualr network following intervention in these readers. Discussion: Our results are in line with the extension of the Simple View of Reading model suggested by Cutting and colleagues (2015). The role of EF in reading in general and in RD in particular as a possible “synchronizer” of reading-related systems as well as the use of possible future executive-functions-based interventions in prereaders will be discussed.

Topic Areas: Development; Reading

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Electrophysiological responses to words with a frequently recurring phoneme in adults with a history of developmental dyslexia

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In auditory word recognition, the sound structure comprising a string of phonemes needs to be mapped onto meaningful representations in the mental lexicon. This mapping may be impeded as a result of phonological deficits that are typical for individuals with developmental dyslexia (DD) and are observable in deviating electrophysiological responses to phonological processing and priming effects during word recognition (Desroches et al., 2013). In the present study, we aimed at enhancing our knowledge about phonological priming effects. We investigated whether the frequent presentation of a certain phoneme may enhance its expectation for a longer period of time and modify the processing of later encountered words. To our knowledge, this is the first study examining effects of sensitization (as a form of priming) on a phonological target structure, as it is already used in intervention for children with speech-sound-disorders, who are at risk for DD (Bruinsma et al., 2020; Kauschke & Siegmüller, 2019). In the present study, event-related potentials were used to investigate effects of a frequently recurring phoneme (termed phonological stimulation) on the processing of German (pseudo)words with this phoneme as onset. The effect of phonological stimulation was investigated in typically reading adults (n = 19) and adults with a self-reported history of DD (n = 13) performing an auditory Lexical Decision Task (LDT) after listening to a short story that was designed to present the phoneme /g/ with a high frequency. In the LDT, it was examined whether the frequent presentation of /g/ leads to a sensitization for this specific phoneme reflected in different electrophysiological responses to (pseudo)words with /g/ as word onset compared to (pseudo)words with a control phoneme (/b/) and further, whether responses to the two sets of (pseudo-)words differ between the two groups of participants. ERP results analyzed with linear mixed-effects models revealed a negativity effect for the frequently presented phoneme in the pre-lexical N100 time-window in typical readers, but not in adults with a history of DD. These findings suggest a reduced sensitivity to phonological information in word onsets in individuals with DD during early processing phases. However, sensitization related modulations of ERPs for this group were observable in the time-windows associated with the N400 and Late Positive Component, indicating an effect of sensitization in later lexical processing stages of word recognition. Furthermore, the typical enhanced N400 effect for pseudowords in comparison to words occurred in the DD-group only for /g/-words, but not for /b/-words. Overall, the findings of the present study provide evidence that phonological stimulation influences the activation of a certain cohort and affects different processing stages of word recognition in individuals with a history of DD compared to typically reading adults. The results do not only suggest that individuals with phonological impairments may benefit from the repeated presentation of a phonological structure, but also that phonological sensitization modulates pre-lexical and lexical processing steps. This points towards implications for interventions involving focused stimulation of specific phonemes in speech and language therapy.

Topic Areas: Disorders: Developmental; Phonology and Phonological Working Memory

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Whole brain grey and white matter structural abnormalities in dyslexia

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Developmental dyslexia is a highly prevalent neurodevelopmental disorder negatively influencing the individual's learning and career outcomes. Studies on its neuroanatomical origins have continued for half a century without consistent results, the most consistent finding being lowered total brain volume. Here, we adopted a whole brain approach and set out to evaluate both the grey matter and white matter structural aberrations in adult dyslexic participants. We used voxel-based (VBM) and surface-based morphometry (SBM) as well as quantitative isotropy aided differential tractography coupled with comprehensive neuropsychological evaluation in a cross-sectional study of 45 adults (23 dyslexic and 22 typically reading participants). In the VBM and SBM analyses, we found both decreased grey matter volume and cortical thickness in the left insula in participants with dyslexia. Moreover, they had decreased grey matter volume in left superior temporal gyrus, putamen, globus pallidus, and parahippocampal gyrus. Higher grey matter volumes and cortical thickness in these areas correlated with better reading and phonological skills, deficits of which are pivotal to dyslexia. Crucially, the total brain volume did not differ between the dyslexic and typically reading groups, suggesting that dyslexia does not (only) rely on brain volume reduction as a predisposing factor or as a de rigueur developmental consequence. Differential tractography analyses revealed structural white matter anomalies in dyslexics in the left ventral route and bilaterally in the dorsal route compared to the controls. Connectivity deficits were also observed in the corpus callosum, forceps major, vertical occipital fasciculus and corticostriatal and thalamic pathways. Altered structural connectivity in the observed differential tractography results correlated with reading skills and phonological processing. Using a whole brain structural and hodological approach, the current study provides novel evidence for the extent of the grey matter and structural connectome aberrations in dyslexia. The results conform current functional neuroanatomical models of reading and dyslexia, but also provide novel network-level and tract-level evidence on structural connectivity anomalies in dyslexia, including the vertical occipital fasciculus. Our results also support the current theories on dyslexia suggesting that it is primarily based on phonological deficits but also associated with significant implicit learning deficits, by associating structural anomalies in dyslexia with neural architectures subserving phonological processing and implicit learning.

Topic Areas: Disorders: Developmental; Reading

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Phoneme category and statistical rule violation detection is impaired in newborns at risk for dyslexia

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In early language acquisition, learning the native language phonemes is an important task. Mastering it requires grouping complex, acoustically variable sounds into categories by implicitly adopting feature conjunctions and temporal regularities from continuous speech, often referred to as statistical learning. Poor categorical phoneme processing, or more generally, implicit learning of sequential information may underlie developmental language disorder and dyslexia, two important neurodevelopmental disorders of language and literacy. In the present study, pre-attentive detection of phoneme category changes (vowel change in a sequence of vowels varying in pitch) and violations of feature rules (rising pitch in vowel pairs violated by occasional falling pitch; variable absolute pitch) were investigated in newborn infants with vs. without familial risk for dyslexia. The two rules pose two levels of difficulty in implicit statistical learning. In healthy infants, both of these rule violations elicited the mismatch response (MMR) of the electroencephalogram, reflecting that a) the violated rule has been detected and encoded by the newborn brain and b) a stimulus was found to deviate from the stored rule. In infants at risk for dyslexia, MMRs to phoneme category changes were diminished and mismatch responses to rule violations were absent. This suggests that implicit statistical learning of language-relevant rules, including phoneme categories, is impaired already at birth in infants at risk for dyslexia. These problems may then contribute to subsequent phonological deficits and to delayed language and literacy acquisition.

Topic Areas: Disorders: Developmental; Speech Perception

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The influence of language similarity on multilinguals' inhibitory control skills

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Managing and communicating in different languages is a routine aspect of successful communication for multilinguals. A particular notable aspect of multilingual language processing is the co-activation and competition of multiple lexical candidates from different languages within a multilingual system. Here, language similarity was reported as a modulating factor, whereby increased co-activation was linked to linguistically similar languages. Simultaneously, increased language similarity was associated with greater difficulties while mitigating co-activation effects. In order to mitigate language co-activation, multilinguals employ an inhibitory control mechanism. Yet, few studies have directly investigated the direct effect of language similarity on inhibitory control skills. Here, we focused on the question whether and how language similarity affects inhibitory skills in the context of a Stroop paradigm. We tested two groups of late language learners of Spanish with different language combinations with varying degrees of language similarity: our first group were 32 Italian native speakers, and our second group were 25 Dutch native speakers with a B1/B2 level of Spanish. The Italian-Spanish group represented the linguistically "similar" group, whereas the Dutch-Spanish speakers represented the linguistically "dissimilar" group. We employed a Stroop paradigm where we exploited the conflict between the semantics of a Spanish target word (e.g., [izquerda] "left", [derecha] "right") and the location of the target word of the screen (left vs. right). We first predicted the classical Stroop effect for both groups, with faster response times for congruent trials (i.e., target word and location matched) compared to incongruent trials (i.e., target word and location did not match). Next, we predicted a main effect of language similarity on response times: we expected Italian-Spanish speakers to be overall faster compared to the Dutch-Spanish speakers. Finally, we predicted an interaction effect between language similarity and condition in the form of a larger Stroop effect for Italian-Spanish speakers compared to Dutch-Spanish speakers. This would yield increased parallel activation and mitigation difficulties for linguistically similar languages such as Italian and Spanish. Our results suggested the following: first, we found a classical Stroop effect, i.e. both groups were significantly faster for congruent than for incongruent trials. In contrast to our hypothesis, Dutch-Spanish speakers were overall faster compared to Italian-Spanish speakers. Further, we did not find evidence for an interaction effect of language similarity and condition: the Stroop effect was comparable across groups. The results therefore suggest a processing advantage for the linguistically dissimilar compared to the linguistically similar language pair in terms of successfully resolving the inherent stimulus conflict of the Stroop task. However, language similarity did not affect Stroop effect size, suggesting a similar degree of inhibitory skills across both groups and therefore a limited role of language similarity in modulating inhibitory control. Our study adds novel evidence to the role of language similarity in a critical component of successful multilingual language processing. In turn, this has important implications for the theoretical understanding of inhibitory control in multilinguals.

Topic Areas: Control, Selection, and Executive Processes; Multilingualism

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Effects of bilingual experience on oscillatory dynamics in inhibition

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At least under specific conditions of individual-level experience/engagement with bilingual language exposure and use, managing multiple languages can lead to structural and functional adaptations in the brain. However, the effects of bilingualism on the neural underpinnings of executive function (EF) remain understudied. Research using time-frequency representations (TFRs) has shown that EF tasks (e.g. Flanker task) modulate power within theta- and alpha frequency bands. These power modulations have been linked to a greater engagement of the executive control system (Cavanagh & Frank, 2014; Suzuki et al., 2018). Herein, we use EEG with a Flanker task to investigate how individual differences in language experience may modulate neurocognitive outcomes (specifically oscillatory dynamics). EEG and behavioral data were collected from 60 bilinguals (28 early bilinguals; 32 late-acquired L2 learners). Participants also completed the Language and Social Background Questionnaire (LSBQ; Anderson et al., 2018). TFRs were computed for both the incongruent- and congruent trials, and the difference between the two (Flanker effect vis-à-vis cognitive interference) was then 1) compared between the early- and later acquired bilinguals (via cluster-based permutations analysis) and 2) modeled as a function of individual differences in language experience using continuous measures of bilingualism derived from the LSBQ. At the group level, we predicted greater brain engagement in early compared to late bilinguals, specifically increased theta activation followed by alpha suppression for the Flanker effect. Furthermore, we hypothesized degree of active bilingualism would predict changes in alpha and beta bands in both early and late bilinguals. Finally, we predicted a correlation between reaction times (RTs) and power modulation within the alpha- and theta bands. Incongruent trials incurred significantly slower RTs than congruent trials, higher theta power in central electrodes 300-600ms post-stimulus onset, and decreased alpha power in centro-parietal electrodes 600-950ms post-stimulus onset. No significant differences were observed between groups for either behavioural or neural responses. However, individual differences analyses revealed significant correlations between age, age of acquisition, and usage of the non-societal language at home with alpha and beta band activity for late bilinguals, whereas only age effects were found in early bilinguals. Furthermore, when correlating alpha power with RTs, early bilinguals showed a negative correlation while later bilinguals show a positive correlation. Taken together, the results indicate adaptations towards differential brain recruitment to deal with the cognitive demands associated with variation in language experience. References Anderson, J. A., Mak, L., Chahi, A. K., & Bialystok, E. (2018). The language and social background questionnaire: Assessing degree of bilingualism in a diverse population. Behavior Research Methods, 50(1), 250–263. Cavanagh, J. F., & Frank, M. J. (2014). Frontal theta as a mechanism for cognitive control. Trends in Cognitive Sciences, 18(8), 414–421. Suzuki, K., Okumura, Y., Kita, Y., Oi, Y., Shinoda, H., & Inagaki, M. (2018). The relationship between the superior frontal cortex and alpha oscillation in a flanker task: Simultaneous recording of electroencephalogram (EEG) and near infrared spectroscopy (NIRS). Neuroscience Research, 131, 30–35.

Topic Areas: Control, Selection, and Executive Processes; Multilingualism

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Determinants of Bilingualism Catalyze Dynamic Changes in Resting State EEG Oscillations

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Bilingualism, at least under specific conditions, can result in a more fine-tuned executive control system and in structural and functional brain adaptations (see for a review Pliatsikas, 2019). Resting state EEG (rs-EEG) activity (frequency power) is related to various cognitive functions and can estimate neurological connectivity (mean coherence) between brain regions. As such, it has emerged in the past few years as a complementary neuroimaging methodological option to investigate the effects of languages (e.g., language learning, bilingualism) in the brain (Bice et al., 2020; Prat et al., 2016). Herein, we use rs-EEG to understand how bilingualism may reshape the mind/brain in a diverse pool of bilinguals. Five minutes eyes-closed task free EEG data from 103 participants (25 were early bilinguals - Italian being the heritage language and German the majority language - and 78 late bilinguals of English in both Germany and Norway) were recorded. All participants completed the Language and Social Background Questionnaire (LSBQ; Anderson et al., 2018), which quantifies language exposure and crucially the division of usage in diverse variety of activities and settings in the participants' two languages over the lifespan. We hypothesized to find positive correlations between linguistic variables (degree of active bilingualism) and frequency bands (especially alpha and beta power), particularly reflected in the posterior brain regions. Furthermore, we expected to observe levels of mean coherence to vary by amount of bilingual language experience. In terms of power frequency, there was a main effect of Age of L2/2L1 onset on high beta and gamma powers (i.e., earlier acquisition resulted in higher beta and gamma frequencies). Higher exposure/usage scores from the LSBQ of the non-societal language at home modulated mean coherence effects (functional brain connectivity) in theta, alpha and gamma frequencies. Results are in line with claims that bilingualism effects are not monolithic, but are rather modulated by degree of engagement with experiential factors. References Anderson, J. A., Mak, L., Chahi, A. K., & Bialystok, E. (2018). The language and social background questionnaire: Assessing degree of bilingualism in a diverse population. Behavior Research Methods, 50(1), 250–263. Bice, K., Yamasaki, B. L., & Prat, C. S. (2020). Bilingual Language Experience Shapes Resting-State Brain Rhythms. Neurobiology of Language, 1(3), 288–318. Pliatsikas, C. (2019). Multilingualism and brain plasticity. In The handbook of the neuroscience of multilingualism (In J. Schwieter (Ed.), pp. 230–251). Hoboken, NJ: Wiley-Blackwell. Prat, C. S., Yamasaki, B. L., Kluender, R. A., & Stocco, A. (2016). Resting-state qEEG predicts rate of second language learning in adults. Brain and Language, 157, 44–50.

Topic Areas: Multilingualism; Control, Selection, and Executive Processes

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Bilingual speakers’ enhanced monitoring can slow them down

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The cognitive demands of bilingualism lead to changes in brain structure and function, particularly in the networks involved in cognitive control (Li et al., 2014; Pliatsikas & Luk, 2016). These changes have been found to lead to behavioural advantages in cognitive control tasks like conflict tasks, but not always (see, e.g., Grundy, 2020). Importantly, cognitive control tasks contain a number of sub-processes. Functional and structural changes might affect these sub-processes in different ways. They might make bilinguals more efficient in some and less efficient in other processes. Performance differences between bilingual and monolingual participants can thus be affected by the balance of various sub-processes. Here we investigated the effect of bilingualism on sub-processes (monitoring and stimulus categorisation) of a conflict task, namely a flanker task (Eriksen & Eriksen, 1974) with congruent (‘>>>>>’) and incongruent (‘>><>>’) arrays of arrows and medium monitoring demand (25% incongruent trials). We examined behavioural and evoked electroencephalographic potentials from a group of young adult bilingual speakers (n=26) and monolingual speakers (n=28). We analysed averaged response times (RTs) and ex-Gaussian analyses of response time distributions. Utilizing an ex-Gaussian analysis allowed to separate a measure of general processing speed (reflected by μ) from a measure of extremeness and frequency of slow responses (reflected by τ). For the evoked potentials we focused on the N2 (implicated to be involved in monitoring) and P300 (implicated to be involved in categorisation) responses. We replicated the flanker congruency effect, both in terms of behavioural and brain responses. In addition, bilinguals had significantly longer response distribution tails (ex-Gaussian τ) compared to monolinguals independent of flanker type, also evident in a trend towards overall slower RTs in bilinguals. Additionally, bilinguals exhibited more pronounced N2 and smaller P3 components compared to their monolingual counterparts, independent of experimental condition, suggesting enhanced bilingual monitoring processes and reduced categorisation effort. Importantly, N2 amplitudes were positively and P3 amplitudes were negatively related to the length of response distribution tails. We postulate that these results reflect an overactive monitoring system (reflected by the more pronounced N2) in bilinguals compared to monolinguals in a task of medium monitoring demand. The enhanced monitoring was followed with fewer resources devoted to conflict resolution and stimulus categorisation (reflected by smaller P3), thus to less effortful categorisation. The monitoring system, however, was rather overactive as it led occasionally to very slow responses. Thus, while the processes of monitoring and categorisation more or less balanced each other out, the less efficient monitoring slightly dominated. These results demonstrate how the efficiency of sub-processes of a task together determine overall behavioural performance and can affect group differences. We propose that the study of the balance of sub-processes in conflict tasks is a fruitful avenue to better understand any functional differences between bilingual and monolingual speakers.

Topic Areas: Multilingualism; Control, Selection, and Executive Processes

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Bilingual experience affects white matter integrity across the lifespan

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Bilingual experience has been reported to change the structure and function of the brain across the lifespan (Bialystok, 2021). In the latter stages of life bilingualism has also been associated with increases in compensatory mechanisms to age-related neurocognitive decline thus delaying dementia symptom onset and leading to a more favorable trajectory of neurocognitive aging more generally (Perani & Abutalebi, 2015). However, most research to date has examined bilingualism-induced effects on neurocognition within one of the above age groups – with middle-aged individuals typically not being a population of interest – meaning there is little evidence for how bilingual experience affects the trajectory of neural decline across the lifespan. Furthermore, bilingualism is often treated as a dichotomous variable, despite it being quite a heterogeneous experience on an individual level (Leivada et al., 2020; Luk & Bialystok, 2013). Therefore, our knowledge of how degree of bilingual engagement modulates neural outcomes across all age groups is insufficient. In the present study we employed diffusion tensor imaging (DTI) to examine whether bilingualism and the degree of engagement in bilingual language use modulates the nature or rate of white matter decline associated with aging. DTI data and language history data, via the language and social background questionnaire (LSBQ; Anderson et al., 2018), were collected from a cohort of monolingual and bilingual individuals (n=78) spanning a wide age range (30-84 yrs.). We investigated mean diffusivity (MD) and fractional anisotropy (FA) values, both in whole-brain as a measure of total brain health, and in several white matter tracts, which are implicated in bilingual language control and aging, including the corpus callosum (CC), bilateral inferior fronto-occipital fasciculi (IFOF), and bilateral superior longitudinal fasciculi (SLF) (Anderson et al., 2018; Gold et al., 2012; Hämäläinen et al., 2017; Luk et al., 2011). Two separate analyses were run. First, generalized additive models were run on a matched monolingual and bilingual sample, examining effects of age on the trajectory of white matter integrity and how bilingualism modulates this effect. This analysis revealed a significant effect of age within the monolingual group for whole brain MD, right IFOF MD, and right SLF FA. However, the age effect within the bilingual group was not significant, indicating a more rapid decline in white matter integrity more rapidly within the monolingual cohort. Second, general linear models were run on the entire participant sample, which examined an interaction between age and degree of bilingual engagement (via continuous measures of bilingualism derived from the LSBQ) on white matter integrity. This analysis revealed a significant interaction of age and degree of bilingual engagement on white matter integrity measures in several regions of interest. Notably, bilingual engagement was found to affect whole brain MD and FA values, indicating that lesser engagement in bilingual language use across the lifespan correlates with a steeper decline in white matter integrity with age. Together these results indicate bilingualism, and, specifically, degree of bilingual engagement, is a significant factor that impacts the trajectory of age-related decline in white matter integrity across the lifespan.

Topic Areas: Multilingualism; Control, Selection, and Executive Processes

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The influence of bilingualism on gray matter volume in the course of aging

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Aging is associated with variable cognitive and cerebral decline [1]. Bilingualism seems to maintain cognitive functioning with aging [2]. A structural correlate of this cognitive advantage during aging is termed brain reserve [3]. Bilingualism was associated with higher gray matter volume (GMV) as a form of brain reserve in the inferior frontal gyrus (IFG) and inferior parietal lobule (IPL) [1, 4]. Interestingly, a cross-sectional study reported a steeper GMV decline for bilinguals [1], which remains to be confirmed longitudinally. Therefore, we investigated trajectories of mono- and bilingual's GMV decline in a large-scale longitudinal study. We included 200 adults (19-79 years, 114 men, 87 monolinguals) from the population-based 1000BRAINS study [5]. The sample was split into younger/older participants (median split: 62.8 years) and monolinguals/bilinguals (assessment: Language Experience and Proficiency Questionnaire [6]). For each participant, T1-weighted MR images were acquired (3T Siemens Tim-TRIO) at two time points (T1/ T2, mean interval 3.6 years). GMV was extracted from four regions of interest (ROIs) (Julich Brain atlas: left/right IFG [7] and left/right IPL [8]) using FreeSurfer's longitudinal stream [9]. For each ROI, mixed Analyses of Covariance (ANCOVAs) were conducted (covariates: sex/education/time interval) to assess (i) GMV changes over time, (ii) GMV differences for language groups (monolinguals/bilinguals) and age groups (younger/older participants) and (iii) the interaction between time point and language group. Results were significant at $p < .05$. There was higher GMV in bilinguals compared to monolinguals in the IPL (left: $p=.023$; right: $p=.021$), but not IFG. For all ROIs, GMV was higher in the younger group. While the left and right IFG and the right IPL displayed a similar GMV change in bilinguals and monolinguals (IFG left: $p=.852$, IFG right: $p=.391$; IPL right: $p=.332$), GMV decline within the left IPL was significantly steeper in bilinguals ($p=.031$). With higher GMV in bilinguals in IPL, but not IFG, bilingualism might contribute to brain reserve especially posteriorly [1]. Higher GMV in the IPL in bilinguals might further reflect more pronounced activation of posterior brain regions during cognitive processing in bilinguals, underpinning the bilingual anterior-to-posterior and subcortical shift model [10]. Importantly, bilinguals show a steeper GMV decline over time in the left IPL, indicating the bilingual's brain reserve to diminish with aging. Contrastingly, mono- and bilinguals' right IPL showed similar GMV changes over time, potentially highlighting a more persistent brain reserve here. Altogether, the current results could not only confirm cross-sectional observations [1] of a steeper GMV decline in bilinguals for the left IPL, but also indicate the necessity to additionally focus on hemispheric differences regarding age-related GMV changes in mono- and bilinguals. 1.Heim, S. et al., Neurobiology Aging, 2019. 2.Bialystok, E., Trends Cognitive Sciences, 2021. 3.Bartres-Faz D., Arenaza-Urquijo E.M., Brain Topography, 2011. 4.Abutalebi, J. et al., Journal Neurolinguistics, 2015. 5.Caspers, S. et al. Frontiers Aging Neuroscience, 2014. 6.Marian, V. et al., Journal Speech Language Hearing Research, 2007. 7.Amunts, K. et al., Journal Comparative Neurology, 1999. 8.Caspers, S. et al., NeuroImage, 2006. 9.Reuter, M. et al., NeuroImage, 2012. 10.Grundy, J.G. et al., Annals NY Acadamy Sciences, 2017.

Topic Areas: Multilingualism; Development

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Neural correlates of left and right branching

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In all human languages the building of hierarchical syntactic structures is thought to rely on the recursive application of a basic binary operation called merge1. While the underlying hierarchical structure created by Merge is constant, the superficial arrangement of elements in a sentence – i.e. linearization- varies cross-linguistically: in right-branching languages like Spanish the object follows the verb [Hemos comprado un libro/(we)Have bought a book], but in left-branching ones like Basque the object comes first [Liburua erosi dugu/book bought have (we)/(we)Have bought a book]. Several studies have investigated the neurobiological bases of merge and linearization operations in right-branching languages. Using functional magnetic resonance imaging (fMRI), Pallier and colleagues parametrically varied the size of syntactic constituents in a visual stream of 12 words and pseudo-words in French. While the pars orbitalis in the left inferior frontal gyrus (IFG) and the posterior portion of the superior temporal sulcus (pSTS) showed increased sensitivity to constituent size both in real- and pseudo-words, the anterior portion of the temporal lobe (TP) mainly responded to real-word stimuli. Further studies in German3 also indicated the pars opercularis of the left IFG as critically involved in basic syntactic structure building. Critically, it is still unclear whether Merge and linearization mechanisms recruit similar neuro-anatomical bases in left-branching languages such as Basque. The comparison between Spanish and Basque can therefore shed light onto this fundamental property of human languages. Fifty-one right-handed young adults, all simultaneous Spanish-Basque bilinguals, participated in an fMRI experiment. Participants were exposed to blocks of 24 visually presented real- and pseudo-words in Spanish and Basque. Similarly to Pallier and colleagues, we manipulated the size of the syntactic phrase(s) by merging pseudo- and real words parametrically: from a determiner phrase [Level1: determiner+noun (Spanish)/noun+determiner (Basque)] to a verb phrase [Level 2: non-finite verb+determiner phrase /determiner phrase+non-finite verb] to a full-fledged sentence [Level3: auxiliary+verb+determiner phrase/ determiner phrase+verb+auxiliary] Results reveal a main effect of syntactic Level: as the stimuli become more sentence-like, a significant increase in activation emerges (Level1Level2>Level3). These results suggest that the neural substrates supporting left branching largely overlap with those supporting right branching in Spanish (and other languages, see2,3). The two linear orders differ, however, in how they engage left IFG regions generally associated with controlled retrieval of semantic information. Further functional connectivity analyses are underway to better characterize the interaction between different syntactic levels and languages in real- and pseudo-word conditions among brain networks. 1 Chomsky (1995) 2 Pallier et al. (2011, PNAS) 3see review in Zaccarella et al.(2017 Neurosci Biobehav Rev.)

Topic Areas: Syntax; Multilingualism

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The Role of RTPJ and LATL in Processing Agreement: Evidence from Hindi

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Verb agreement is important because it facilitates identifying the arguments of a verb. Theories differ on whether agreement is interpreted by actively encoding information pre-verbally or by retrieval processes post-verbally. Identifying the neural generators of agreement has been challenging, as they are confounded with other syntactic relations, e.g., thematic roles. Here, we exploit Hindi split-ergative agreement, in which verbs may agree in gender with the subject, object, or neither depending on case marking. By examining the neural response to bare objects that control agreement vs. those that do not in magnetoencephalography (MEG), we show that RTPJ and LATL are both implicated in preverbal agreement processes. [MATERIALS] We prepared 46 sets of 8 items, manipulating SubjCase {Erg/Bare}, ObjCase {Acc/Bare}, and Verb Cloze {High/Low}. Sentences consisted of a subject, object, and verbal complex. NP genders differed and were counterbalanced. [PROCEDURE] MEG signals were recorded for 12 (/24 planned) native Hindi speakers while reading Standard Hindi sentences. Each phrase was displayed 900ms on 100ms off. After 25% of trials, participants completed a picture verification task. [RESULTS] Five lateral ROIs per hemisphere plus bilateral vmPFC were selected. Test statistics were computed over average activation levels (dSPM) in each time point per ROI, and in each time and source in the whole brain. We then conducted cluster permutation tests to identify significant clusters. Test statistics were F-values from ANOVAs (dSPM ~ SubjCase × ObjCase in object NP time window, 0-1000ms; … × Cloze in verb time window, 1000ms–2000ms), or t-values resulting from one-tailed t-tests over beta coefficients resulting from regressions at each time point and source per subject (dSPM ~ SubjCase × ObjCase + NP Gender + Verb Gender + List Position + log(Lexical Frequency) + Verb Entropy, 0–1000ms; … + Cloze, 1000–2000ms). ROI analyses revealed significant clusters in right temporo-parietal junction (RTPJ) in object time window: ObjCase × SubjCase interaction in ANOVAs ($p = 0.01$; 360–440ms) and ObjCase effect in regressions ($p = 0.04$, 360–430ms). Cloze results were identified in ventro-medial prefrontal cortex (vmPFC) ($p = 0.01$, 1480–1580ms; $p = 0.01$, 1630–1690ms) in ANOVAs, and left posterior temporal lobe and occipital lobe (LPTL+lOCC) in regressions ($p = 0.04$, 1400–1450ms; $p = 0.05$, 1330–1380ms. There was an effect of Verb Gender in the pre-verbal object time window in left anterior temporal lobe (LATL) ($p = 0.03$, 580ms–630ms), also in whole-brain regressions ($p = 0.05$; 510–920ms). No effects were found in other ROIs. [DISCUSSION] These preliminary findings suggest that RTPJ is sensitive to case around 400ms after onset of object, and LATL is sensitive to the predicted gender feature 200ms afterwards. RTPJ is implicated in the ventral attentional network and in shifting attention to relevant stimuli. We suggest that processing the lexical features of the object activates its morphosyntactic features. If the structure requires object agreement, then RTPJ is engaged to shift attention from the subject's features to those of the object. These features are represented in LATL, a "conceptual hub" implicated in linguistic composition.

Topic Areas: Syntax; Morphology

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Greater gyrification of right Heschl's gyrus is related to better auditory language comprehension in patients with left hemisphere stroke

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In aphasic patients with left hemisphere stroke, better auditory language comprehension has been associated with (i) activation of areas anterior to right auditory cortex (Crinion & Price, 2005; Wilson & Schneck, 2021) and (ii) higher grey matter volume in right middle temporal gyrus (Lukic et al., 2017). A structural index that hasn't been investigated in association with outcome after stroke is gyrification of the auditory cortex. Greater gyrification of left Heschl's gyrus (HG), which includes the primary auditory cortex, has been linked to better non-native speech sound learning (Golestani et al., 2007) and to phonetic expertise (Golestani et al., 2011), and greater gyrification of right HG has been related to higher language aptitude (Turker et al., 2017). It remains to be seen how the degree of gyrification in HG of aphasic stroke patients relates to auditory language comprehension. We examined the relationship between right HG morphology and auditory language comprehension in left hemisphere stroke patients. 20 chronic stroke patients (mean age=54 years, SD=12, 2 females) with 100% damage to the left auditory cortex were selected for whom we had structural MRI data and comprehensive aphasia test (CAT) behavioural scores. Performance on a spoken paragraph comprehension task was evaluated. T1's were processed with Freesurfer v.5.3 and the Toolbox for Automated Segmentation of Heschl's gyrus (TASH) (Dalboni da Rocha et al., 2020), to automatically label right HG. The TASH HG labels were then used to visually (i) classify the gyri (single vs. common stem duplication) and (ii) determine the degree of gyrification, with higher values corresponding to a longer intermediate sulcus. Ratings were performed independently by two authors and showed a high correspondence ($r=0.96$). A partial correlation between the gyrification measure and spoken paragraph comprehension task was performed. 14/20 patients scored below the normal range on the spoken paragraph comprehension task. Right HG common stem duplication was observed in 5/6 (83%) of patients with normal paragraph comprehension, but only in 3/14 (~20%) of patients with aphasic scores. This difference is significant ($p = 0.018$, Fisher's exact test). Further, there was a positive correlation between gyrification of right HG and spoken paragraph comprehension ($r(18)=.66$, $p=.01$), when controlling for age at stroke, gender, lesion volume, years of education, months since stroke, native language, and scanner. The findings of the present study are the first to show a positive association between gyrification in the right HG and auditory language comprehension in stroke patients with lesions to the left auditory cortex. The observed behavioural advantage of greater gyrification is in line with previous findings in language experts (Golestani, et al. 2011) and in relation to language aptitude (Turker et al., 2017). Although this is a cross-sectional study, it might be that the observed gyrification differences are not due to plasticity after stroke, but rather reflect pre-morbid differences due to the likely relative stability of auditory cortex morphology (Chi et al., 1977). Next steps include replicating our visually determined gyrification results with those derived from a novel automated toolbox (Dalboni da Rocha et al, in preparation).

Topic Areas: Perception: Auditory; Disorders: Acquired

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Language experience affects predictive coding during auditory rhythm perception

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According to Predictive Coding models of the auditory cortex, the auditory system constantly extrapolates the rules governing recent inputs and uses such models to generate prediction of incoming sensory events. This operation is central to tracking meaningful structures during auditory rhythm perception. In this study, we investigate whether the auditory system generates predictions based on lifelong exposure to linguistic regularities, using rules that extend beyond those acquired in the recent past. We compare magnetoencephalography (MEG) data from native speakers of Basque and Spanish who performed a rhythmic version of the alternation paradigm with omission responses. Basque and Spanish are two languages that differ in their syntactic/prosodic structure, thus providing an ideal model to study the effect of linguistic experience on auditory predictive processing. Spanish is a functor-initial language, in which short events (i.e., function words; e.g., la, the) usually combine with long ones (i.e., content words; e.g., casa, house), thus forming “short-long” higher-level chunks. On the other hand, Basque is a functor-final language, in which long events (i.e., content words; e.g., etxera, house) usually form phrasal chunks with short events (i.e., function words; e.g., bat, the), resulting in “long-short” grouping units. We hypothesize that the auditory system extrapolates abstract schemes underlying the phrasal structure of language, and use such knowledge to generate long-term predictions about incoming sounds. To test this hypothesis, we present subjects with 30s rhythmic sequences of two tones alternating in duration (short tone = 0.250s; long tone = 0.435s) at fixed intervals (0.020s). In each sequence, two to six tone omissions occur pseudo-randomly. MEG responses to omitted sounds are recorded. A hierarchical predictive coding model predicts that the omission of a short tone represents the violation of two predictions in Spanish, but not in Basque: a local prediction, based on the transitional probabilities of previous stimuli, and a long-term, language-induced prediction based on the regularities of Spanish syntax/prosody. The opposite pattern is expected in the Basque group. Results show that unexpected omissions elicited a sharp “Mismatch Negativity” (MMN) – a neural response putatively associated to cortical prediction error. Importantly, the amplitude of the MMN varied orthogonally depending on the individual’s linguistic background. The omission of a short tone elicited a larger MMN in Spanish compared to Basque native speakers. On the other hand, the omission of a long tone elicited a larger MMN response in the Basque compared to the Spanish group. This prediction error signals occurred around 0.100s from deviant onset, and had their locus in auditory regions. This finding indicates that the auditory system recycles coding schemes employed to parse linguistic information to implement predictive models of non-linguistic sound sequences. These results provide support for the proposal that shared computational resources underlie speech, sound, and music processing.

Topic Areas: Perception: Auditory; Prosody

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Words in the CLOUD: How orthographic similarity and bilingual experience facilitate foreign vocabulary learning

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Learning a foreign language as an adult is a rewarding but challenging endeavor that entails accruing a massive vocabulary to achieve adequate proficiency. The literature highlights that orthographic similarity and bilingual experience independently facilitate foreign vocabulary acquisition. Intuitively, a word that looks more similar to a known language should be easier to learn regardless of its meaning; and the knowledge of two languages—bilingualism—could provide an advantage in terms of sources from where to draw similarities. However, despite numerous efforts to formalize the development of the mental lexicon with computational approaches, the basis for these vocabulary learning effects remains largely unexplored. Here, we explored the combined effects of orthographic similarity and bilingual experience on foreign vocabulary learning using behavioral and computational approaches. First, we compared Spanish monolingual, Spanish-English, and Spanish-Basque bilingual participants (n = 40 per group) when learning an artificial vocabulary with varying orthographic similarity to Spanish. The vocabulary contained 24 orthographically similar and 24 dissimilar novel words, paired with black and white depictions of real objects. Participants performed a familiarization and five active learning blocks where they recognized and produced the novel vocabulary. Growth curve analyses on these data revealed that both bilingual groups outperformed the monolingual group, better recognizing and producing the novel words across the blocks regardless of their similarity to Spanish. Additionally, as expected, orthographically similar words were easier to recognize and produce than dissimilar words. As a second step, we developed the CLOUD—Constrained Learner of Orthography: Unified, Distributed, and Dynamic—model, a character-level recurrent neural network that can learn written vocabulary by implementing a unified, distributed, and dynamic view of the orthographic lexicon. We simulated adults' orthographic lexicons by pre-training this architecture on monolingual and bilingual input using around 17,000 words. The monolingual and bilingual versions' accuracy was matched using an adapted lexical decision task. After pre-training and matching the models, we tested the monolingual and bilingual models' capacity to learn the novel words used in our behavioral task. Crucially, the models could emulate the orthographic similarity effects and showed an overall advantage of experience with bilingual input, as observed in the behavioral results. Past research has highlighted orthographic similarity and bilingual experience as independent catalysts of foreign vocabulary learning. The present study is first in unifying these seemingly disparate findings under a common computational framework, whereby distributed representations of orthographic word forms are stored in a unified space and dynamically modified by learning experiences. Our model could simulate participants' behavior, corroborating the influence of orthographic similarity and showing a bilingual advantage for receptive and productive vocabulary. This conceptualization has implications regarding how consistent experience with specific words in different linguistic contexts (i.e., bilingual settings) can influence foreign vocabulary acquisition. Our work opens up exciting pathways for further investigating the cognitive and computational mechanisms of foreign vocabulary learning.

Topic Areas: Multilingualism; Computational Approaches

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One-year re-test reliability of fMRI signals of auditory and visual language processing in elderly healthy adults

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Reliability of data is a current issue in cognitive neuroscience and neurolinguistics. Moreover, from a clinical perspective, the longitudinal stability of activation patterns in the brains of healthy seniors is an important prerequisite for the assessment of pathological development in neurodegenerative diseases or neural recovery after stroke. Consequently, we analysed the re-test reliability of fMRI activation patterns of word and pseudoword processing over the course of one year. Twenty-eight healthy adults (57-72 years, mean 62.6 years, 14 women) performed lexical decision tasks on these stimuli in both the auditory and the visual modality. Stimuli were presented in pseudo-randomised order for word type in two separate runs, one for each modality. The networks for auditory and visual lexical access at time point T1 were identified (cf. Heim et al. 2019) and served as masks for the present analysis of auditory or visual processing, respectively. Re-test reliability was assessed using voxel-wise inter-class correlations (ICC; Specht et al. 2003; Specht 2020) as ICC(3,1) = BMS-EMS/(BMS+EMS) using the individual spmT-images thresholded for such voxels that showed an activation of T>3.09 as input. At a threshold of ICC>.60 with cluster size k=20 voxels, ICCs>.80 were observed in the modality-specific language areas in both modalities. Auditory words and also auditory pseudowords yielded such effects in the auditory cortices and auditory association areas in the left and right STG. Similarly, visual words and also pseudowords had comparable ICC coefficients in the left and right MOG and the visual word form area in the left ITG/IOG. In Broca’s region in the left IFG, which forms a joint area for lexical access in both modalities, sufficiently high ICC coefficients were found for auditory words (ICC=.74) and visual pseudowords (also ICC=.74). The data indicate the overall reliability of fMRI activation patterns during word and pseudoword processing in both modalities, in particular in the modality-specific cortical areas but also in the amodal cortex of Broca’s region. These data support the notion that, for clinical studies, a one-time assessment of a healthy senior control group may suffice for the quantification of longitudinal changes in patient groups. References Heim, S., Wellner, B., Fimm, B., Jockwitz, C., Caspers, S., & Amunts, K. (2019). How cognitive abilities modulate the brain network for auditory lexical access in healthy seniors. 11th Annual Meeting of the Society for the Neurobiology of Language, p. 98. Specht, K., Willmes, K., Shah, N.J. and Jäncke, L. (2003), Assessment of reliability in functional imaging studies. J. Magn. Reson. Imaging, 17: 463-471. https://doi.org/10.1002/jmri.10277 Specht K. Current Challenges in Translational and Clinical fMRI and Future Directions. Front Psychiatry. 2020 Jan 8;10:924. doi: 10.3389/fpsyt.2019.00924.

Topic Areas: Meaning: Lexical Semantics; Disorders: Acquired

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Conserved and divergent connectivity principles across the primate phylogenetic tree

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The primate brain has undergone massive shifts in shape, size, microstructure or connectivity across evolution. While comparative neuroscience typically aims to uncover these changes and associate them with differences in cognition, it is equally useful to look at common components across different species. These conserved elements can serve as a baseline on which to compare species with a common ancestor and offer valuable insights on the principles of organization of a taxonomic group. Recently, non-negative matrix factorization has been proposed as a way to map white matter bundles and their respective grey matter networks from diffusion tractography data. Here, we adapt the technique to use connectivity blueprints instead, leveraging on their common space approach to map common and divergent connectivity principles across the primate phylogenetic tree. Publicly available connectivity blueprints for human , chimpanzee and macaque were used. Connectivity blueprints are obtained by computing the probabilistic tractography matrices seeding from the cortex to the rest of the brain and multiplying them with individual tract maps for 22 common tracts. Thus, at the vertex level, they represent the probability of streamlines from a given vertex to connect to each of the 22 chosen tracts. Five sets of bilateral connectivity blueprints were created: 3 with the average blueprint of the 3 species in question, a primate ancestor common blueprint by concatenating all 3 species' blueprints and a great ape common ancestor blueprint by concatenating only human and chimpanzee blueprints. Non-negative matrix factorization was applied to each of the 5 sets under consideration and the resulting white matter tract components were compared in the following way: the macaque was compared with the primate common ancestor, the great ape common ancestor with the primate common ancestor, and finally, the chimpanzee and human components with the great ape common ancestor. Our analysis gives several important insights. First, it is clear that the only major shift from the primate common ancestor to the macaque is at the level of the vertical occipital tract (VOF), confirming its influence on the Macaque-unique visual fields. Second, we see that despite the arcuate fasciculus (AF) being one of the most iconic 'human-unique' fiber bundles, some aspects of AF connectivity are shared between humans and chimpanzees, suggesting that the foundation of our language system may already have been in place as far as 6 million years ago. Also, at the great ape common ancestor level, a strong motor component can be seen in the form of novel connections from the frontal aslant and superior thalamic radiation. Finally, it appears that the greater changes that happened to the chimpanzee since its divergence from the great ape common ancestor are mostly related to inferior longitudinal fasciculus reweighting and some modifications to the temporal portion of the cingulum bundle. In summary, we found conserved and species- specific principles of connectivity suggesting that the white matter basic infrastructure for language may have been present already at the level of our last common ancestor with the chimpanzee.

Topic Areas: Methods; History of the Neurobiology of Language

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Explaining semantic cognition in aging — evidence from a longitudinal large-sample study

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Healthy aging is accompanied by cognitive changes. It is generally assumed that different cognitive domains follow their own life-span trajectories: while cognitive abilities supported by fluid intelligence peak in early adulthood and decline thereafter, signatures of crystallized intelligence like vocabulary and knowledge remain relatively stable or even increase with older age (Hartshorne & Germine, 2015). Based on this simplistic distinction, one might hypothesize that semantic cognition, built on our accumulated knowledge about the world, is generally preserved in older age. However, performance in tests of semantic cognition does not only rely on the preservation of knowledge itself. Semantic cognition also requires high fidelity in the executive control processes operating around it. Notably, performance of older compared to younger adults was recently found specifically impaired in a task requiring the controlled selection of task-relevant and the suppression of competing, task-irrelevant semantic information (Hoffman, 2018). We here follow up on this effect in a longitudinal cohort of age-varying adults (N=101, 42–82 years, median at T2 = 63 years). First, we aimed at replicating the opposing effects of age on verbal intelligence and semantic control processes, and further probed their age-independent relationship. Second, we hypothesized that controlled selection abilities are largely reflective of domain-general executive control. Selection performance in semantic cognition of healthy ageing adults should thus be predictable from neural signatures of executive control recorded in an independent task approximately 1.5 years earlier. We assessed verbal intelligence using the spot-the-word test, and administered a novel German version of the 2x2 design by Hoffman (2018) which contrasts performance under different tasks (retrieval vs. selection) and levels of control demand (low vs. high). As signatures of executive control, we used the degree of 8–12 Hz alpha power lateralization and selective neural speech tracking during a difficult dual-talker listening task (Tune et al., 2021). As expected, increased age led to a decrease in accuracy that was specific to the more difficult condition (i.e. requiring a high level of control) of the controlled selection task (Task x Control demand x Age interaction; odds ratio (OR) = .67, standard error (SE) = .2, $p < .5$). By contrast, we observed a positive trend of verbal intelligence scores with increased age (β=.18, p=.08). When controlling for age, we found accuracy in the controlled selection task positively associated with verbal intelligence ($\beta = .37$, SE = .09, $p <.001$). Additionally, accuracy was predicted by the degree of alpha power lateralization ($\beta = .23$, SE = .09, $p <.05$), speaking to their joint involvement in executive control processes. Taken together, we provide converging evidence for the contribution of different cognitive domains to an individual's abilities jointly referred to as semantic cognition, and for the opposing forces increased age exerts on them. The results highlight the importance of teasing apart the influences of crystallized and fluid intelligence when examining age-related performance changes in various semantic tasks.

Topic Areas: Meaning: Lexical Semantics; Control, Selection, and Executive Processes

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The N400 ERP component reflects a learning signal during language comprehension

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The functional significance of the N400 is still actively debated. Recently, theories and computational models of the N400 have increasingly focused on a prediction error perspective. Error-based learning accounts state that when the input deviates from expectations, prediction errors occur and allow for an adaptation of the current internal model to make better predictions in the future. This offers a straightforward hypothesis: if larger prediction errors (i.e., N400s) lead to greater adaptation, this should be reflected in enhanced implicit memory. Here, we investigated this prediction by experimentally manipulating target word predictability (cloze probability) in a sentence reading task, while recording participants' EEG. After a short break to avoid explicit memory effects, participants were presented with an implicit memory task that allowed the recording of reaction times corresponding to the identification of the previous target words (perceptual identification task). We analyzed our data using linear mixed effects models with random by participants and by items intercepts and slopes and included word frequency as an additional fixed effect. We hypothesized that words that elicit larger N400s during sentence reading (low cloze completions) would show enhanced implicit memory as indicated by faster responses in the subsequent perceptual identification task. As expected, the manipulation of cloze probability in the sentence reading task influenced N400 amplitude in response to the critical word. Crucially, as hypothesized, previously low-cloze (unexpected) words did not only elicit larger N400 amplitudes ($\beta = 1.32$ µV, SE = .375, $t = -3.511$, $\chi 2 = 10.475$, $p = .001$) than high-cloze (expected) words but were also recognized faster in the subsequent implicit memory task ($\beta = -0.037$, SE = 0.008, $t = -4.557$, $\chi 2 = 17.764$, $p < .001$). To investigate the relationship between N400 amplitude and the implicit memory effect more directly, we computed the correlation between participants' N400 differences in the expected minus unexpected condition during sentence reading and the respective reaction time differences in the subsequent implicit memory task. Results demonstrated that participants with greater N400 amplitude difference also showed a greater implicit memory benefit for previously unexpected words ($r = 0.46$ [95 % CI: 0.14, 0.70], $p = .007$). To examine the specificity of the observed link between N400 amplitudes and subsequent implicit memory, we additionally investigated post N400 positivities related to unexpected sentence continuations. While there was a significant late frontal positive ERP effect in our EEG data ($\beta = 0.635$, SE = 0.304, $t = 2.091$, $\chi 2 = 4.217$, $p = .04$), no support for a correlation between its amplitude and implicit memory differences was found ($r = -0.015$ [95 % CI: -0.33, 0.36], $p = .936$). We conclude from the results that larger N400 amplitudes lead to increased implicit memory formation. This is in line with the interpretation of the N400 as a prediction error that drives adaptation and learning. The correlation between within-participant differences makes it unlikely that expectancy independently influenced N400 amplitude and implicit memory. Rather our findings support the idea that the N400 ERP component reflects a learning signal during language comprehension.

Topic Areas: Meaning: Lexical Semantics; Meaning: Combinatorial Semantics

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Cortical dynamics supporting the early integration of sound and meaning in human speech interpretation

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Human speech comprehension depends on the dynamic integration of speech inputs with contextual constraints to enable the rapid and robust incremental interpretation of the current utterance. Here we focus on the earliest stages of this process, to determine how contextual constraints (typically generic in nature rather than lexically specific) interact with very early cues in the speech input to constrain word choice within the first 150 ms after word onset. To map out the cortical dynamics of the neurocomputational infrastructure that supports these core integrative processes, we combine MEG and EEG measures of real-time brain activity with ASR and NLP computational models of linguistic form and content and multivariate imaging analysis methods (Representational Similarity Analysis [RSA], Grainger Causal analysis [GCA]), and apply these to data-driven whole-brain procedures (ICA) for segmenting brain activity into potential component networks. We uniquely identify a distributed LH fronto-temporal network that integrates acoustic-phonetic cues and contextual constraints to support the early identification of lexical form and meaning. This integration process is not visible at word-onset, suggesting that bottom-up constraints are necessary to set the representational geometry of an analysis space with which semantic constraints can interface. A parallel RH fronto-temporal network shows strong sensitivity to acoustic-phonetic and phonological models, but no systematic response to semantic models. Using data-driven methods to decompose the LH network into temporal and frontal centres of gravity, we combine GCA measures of connectivity with RSA analyses of the representational content of the patterns of connectivity within the network. We find a continuous interchange of semantic and phonological constraints between regions, with some evidence of a stronger role for BA47 in semantic processing and BA45 in phonological processing. Overall, these results open a novel scientific window on the mesoscale cortical dynamics underpinning incremental speech interpretation.

Topic Areas: Meaning: Combinatorial Semantics; Computational Approaches

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The left Angular Gyrus tracks episodic but not semantic content during narrative comprehension.

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Language processing involves the construction of complex mental representations, i.e., “event representations”, reflecting current events or situation models. The left angular gyrus (AG) has been often associated with the formation of this type of representations. However, to date, it is unclear whether AG supports the construction of the semantic content of these representations independently from their episodic content, and vice versa. In this fMRI study, we established the unique neural correlates of (1) episodic richness and (2) semantic coherence measured during a narrative reading task. Interestingly, we observed that the number of episodic details in the narratives modulated linearly the activity of the left AG. In contrast, semantic coherence modulated neural responses in the right anterior temporal lobe/middle temporal gyrus, as well as in other brain regions within the posterior medial network, such as the dorsal posterior cingulate cortex.

Topic Areas: Meaning: Combinatorial Semantics; Meaning: Lexical Semantics

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Cortical tracking and the relationship between structure and meaning

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It is well-established that brain activity ‘tracks’ low-level aspects of speech stimuli, such as the amplitude envelope (e.g., Peelle & Davis, 2012). Recent studies show that cortical tracking also occurs at the presentation rate of abstract information, such as syntactic phrases (Ding et al., 2016; Keitel et al., 2018), and that such phrase structure tracking is modulated by the content of these phrases. In a recent EEG study, Kaufeld et al. (2020) found that phrase structure tracking is stronger for compositional sentences than for control stimuli that had lexical content but no structure (i.e., word lists) and prosodic and syntactic structure but no lexical content (i.e., jabberwocky), suggesting that this neural response is driven by compositional structure and meaning (Martin, 2020). Following up on this idea, the current EEG study examines to what extent cortical tracking of linguistic structure is modulated by the compositionality of that structure. We measured EEG of 38 participants who listened to naturally produced stimuli in five different conditions, which systematically modulated the amount of linguistic information. We compared sentences (+syntax, +lexical meaning, +composition) to idioms (+syntax, +lexical meaning, ~composition), syntactic prose (+syntax, +lexical meaning, ~composition), prosodic jabberwocky (+syntax, –lexical meaning), and word lists (–syntax, +lexical meaning), and included backward versions of sentences and word lists as acoustic controls. Based on manual annotations of all speech recordings, we derived frequency bands corresponding to the presentation rate of phrases (1.1-2.1 Hz), words (2.3-4.7 Hz) and syllables (3.4-4.9 Hz). Tracking was quantified through Mutual Information (MI) between the EEG data and the envelope of the speech stimuli in each of these frequency bands. The higher the MI value, the stronger the statistical relationship between the two input signals. We consistently found that, in the phrase frequency band, MI between speech and EEG was higher for sentences than for prosodic jabberwocky, but not higher than for idioms or syntactic prose. This result was also found when MI was computed between the EEG signal and abstract annotations that represented either the presence of closing phrase boundaries or the number of closing phrase boundaries (‘bracket count’). Phrase structure tracking was also higher for sentences than for word lists, but this difference was also found for the backward versions of these stimuli and could therefore reflect a difference in their acoustics. Overall, phrase structure tracking was stronger for sentences than for stimuli that lacked either lexical meaning or syntactic structure, but it was not consistently different from stimuli which had lexical meaning and syntactic structure. These findings suggest that cortical tracking of linguistic structure reflects the generation of structure (Martin, 2020; Meyer et al., 2019), whether this structure straightforwardly maps onto semantic meaning or not. This is in line with models of language comprehension which make a functional distinction between syntactic structure building and semantic composition (Baggio, 2018; Hagoort, 2005). As our findings map most strongly onto the process of structure building, an important question for future research is how the brain computes the compositional meaning of this structure.

Topic Areas: Meaning: Combinatorial Semantics; Syntax

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N400 amplitudes reflect change in a probabilistic representation of meaning: Evidence from large scale modelling

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The N400 component of the event-related brain potential (ERP) is widely used in research on language and meaning processing, but its functional basis remains actively debated (Kutas & Federmeier 2011). Recent work showed that the update of the predictive representation of sentence meaning (semantic update, or SU) generated by the Sentence Gestalt (SG) model (McClelland et al. 1989), a neural network model of sentence comprehension, consistently displayed a similar pattern to the N400 amplitude in a series of conditions known to modulate this event-related potential, suggesting that the N400 might reflect the change in a probabilistic representation of meaning corresponding to an implicit semantic prediction error (Rabovsky et al. 2018). In previous work, the model was trained on a small artificial training corpus and thus could not be presented with the same naturalistic stimuli presented in empirical experiments, making the testing of the hypothesis implemented in the model also somewhat indirect and based on the assumption that the small synthetic environment adequately captures the relevant statistical properties of human environments. In the present study, we attempt to directly predict the amplitude of the N400 generated during sentence processing by using as predictor the update of the inner representation of a SG model trained on a large corpus of naturalistic texts (part of the Rollenwechsel-English corpus (Sayeed et al. 2018). We used EEG data collected while subjects were asked to read sentences (Frank et al. 2015). We fit a linear mixed effect model predicting the N400 amplitude as a function of the SU over the stimulus words. The results indicate that SU significantly predicts the amplitude of the N400 ($\beta = 0.07$, $z = 9.52$, $p < 0.001$). Larger word-wise updates of the SG layer representation correspond with a stronger negative deviation of the ERP signal in the N400 time segment. Moreover, to assess the contribution of the SU on the amplitude of the N400 beyond the effect of surprisal, previously shown to predict N400 amplitudes (Frank et al. 2015), we fitted two nested linear mixed-effects models, one containing as predictors only surprisal, the other containing also the SU. The log-likelihood test between the two models showed that the fit of the model including SU was significantly better ($\chi2 = 79.03$, $p < .0001$). Even with the presence of surprisal ($\beta = -0.06$, $z = -8.08$, $p < 0.001$), SU makes a significant contribution to the amplitude of the N400 ($\beta = 0.06$, $z = 8.90$, $p < 0.001$). The present analyses showed a significant relation between the amplitude of the N400 and the update of the probabilistic semantic representation (SU) generated by the corpus-trained SG model. Further analyses indicate that word position, word frequency, and surprisal have similar effects on the SU as they have on N400 amplitudes. These results suggest that the SU is a valid approximate of the N400, in line with the hypothesis that its amplitudes reflect the change in a probabilistic representation of sentence meaning corresponding to an internal prediction error at the level of meaning.

Topic Areas: Computational Approaches; Meaning: Combinatorial Semantics

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Neural tracking of syntax from a cross-linguistic perspective

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Recent findings suggest that neural activity tracks abstract syntactic structures during language comprehension. Using the frequency-tagging paradigm, it has been shown that low-frequency neural responses selectively align to the periodic presentation of multi-word chunks corresponding to syntactic phrases and sentences (Ding et al., 2016). Importantly, despite being replicated in several languages (e.g., Makov et al., 2017; Sheng et al., 2018), neural tracking of syntax has always been tested in head-initial (e.g., verb-before-object) constructions. As typologically different languages display other word order (e.g., head-final like object-before-verb) configurations, this gap clearly limits the cross-linguistic coverage of current syntax-tracking findings. In this magnetoencephalography study, we investigate neural tracking of syntactic structure from a cross-linguistic perspective. Following Ding et al., (2016), we implement the frequency-tagging paradigm but in the visual modality by periodically presenting sequences of written words to be combined into certain structures at different frequencies. Our aim is to assess whether and how neural tracking of syntax is modulated by the word order characteristics of head-initial and head-final structures in Spanish and Basque, respectively. Spanish-Basque bilinguals (n = 33) were presented with trials of 12-second sequences of 24 chunks with written words (500 ms per chunk: 350 ms display + 150 ms blank screen; single-chunk presentation frequency: ~ 2 Hz), corresponding to three different syntactic structures in either language: 1-chunk Noun Phrases (NPs; [Article Noun] in Spanish and [Noun-Article] in Basque), 2-chunk (verbal) phrases ([Verb] [NP] in Spanish and [NP] [Verb] in Basque), and 3-chunk sentences ([Auxiliary] [Verb] [NP] in Spanish and [NP] [Verb] [Auxiliary] in Basque). Our syntactic frequencies of interest were ~ 1 Hz for 2-chunk phrases and ~ 0.67 Hz for 3-chunk sentences. We report frequency-domain results of normalized power and inter-trial phase coherence (ITPC), which reflect frequency-specific neural tracking in terms of amplitude modulations and consistent phase alignment over time, respectively. Sensor-averaged results show peaks at ~ 2 Hz in all conditions, corresponding to the presentation frequency of single chunks. Moreover, 2-chunk phrases and 3-chunk sentences reveal additional peaks at ~ 1 Hz and ~ 0.67 Hz, respectively, in both Spanish and Basque. This suggests that syntax tracking emerges similarly in both languages regardless of their word order. However, certain discrepancies in the fronto-temporal sensor distribution of these effects indicate a more complex scenario. More concretely, although syntax tracking effects are distinctly lateralised (bilateral vs. left-hemispheric extension) between languages, this lateralisation also varies within each language depending on the type of syntactic structure (2-chunk phrases vs. 3-chunk sentences), suggesting the intervention of other factors beyond word order. In addition, while power and ITPC effects in 3-chunk sentences mainly show comparable distributions within each language, the sensor extension of ITPC – relative to power – effects in 2-chunk phrases is reduced considerably in Spanish and dramatically in Basque. This power-ITPC dissociation might indicate variable phase alignment to the frequency of phrases over time, particularly in Basque. Despite certain unresolved issues, our sensor-level results provide novel cross-linguistic evidence for neural tracking of syntax in head-initial as well as head-final structures.

Topic Areas: Syntax; Meaning: Combinatorial Semantics

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Overlap in neural processes in the comprehension and production of discourse.

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When comprehending discourse, people construct a situation model of its content (Kintsch & van Dijk, 1978). In the brain, this process engages the default mode network (DMN), which shows greater activation during the comprehension of coherent relative to incoherent text (Ferstl & von Cramon, 2002), and maximal activity when it is difficult, but not impossible, to construct a situation model from discourse (Kuperberg et al., 2006). Importantly, situation model processes are thought to guide production as well as comprehension of language (Garrod & Pickering, 2004). However, very little is known about how these processes overlap in the brain during the comprehension and production of speech within participants. To address this issue, we compared the neural correlates of coherence during the production and comprehension of discourse. In a fMRI study, 25 participants produced and listened to speech about a range of different topics. We computed the coherence of this discourse as a time-varying measure that indexed the natural fluctuations of coherence that occurred in the speech. As discourse processing relies on distributed networks, we took a network-level approach to analyse our data. At the whole brain level, we investigated the effects of coherence along the principal connectivity gradient, which describes the functional organisation of cognitive processes in the brain (Margulies et al., 2016). This gradient situates the DMN at one extreme of this spectrum, associated with multimodal high-level abstract thought, with sensorimotor networks engaged in more basic processes at the other end. To confirm and extend the results from this analysis, we also investigated the effects of coherence on three specific networks: the DMN, the semantic control network (SCN), and the multiple demand network (MDN). Results showed that overall, production and comprehension of discourse activated the same left-lateralised neural networks. In addition, people activated the DMN more when they listened to less coherent speech, suggesting they frequently updated and reconfigured their situation models during comprehension of low-coherence speech. Critically, our study reveals that these effects were also present when people produced their own speech, suggesting a role for situation models in planning and generating speech content just as it occurs in comprehension. In contrast, coherence effects diverged between production and comprehension processes in the SCN, with greater activation when participants listened to less coherent discourse, but not when participants produced less coherent speech. In addition, the sensorimotor part of the gradient showed greater activation when discourse was less coherent during speech comprehension, which was not present during speech production, thus indicating that low-level sensorimotor networks were more engaged when participants listened to speech that deviated from the expected topic. Finally, results showed no coherence effects in the MDN for either task, suggesting that higher levels of language processing draws on specific neural resources distinct from those engaged in other cognitive domains. Overall, our results show that neural mechanisms implicated in the construction of situation models are largely shared between the production and comprehension of discourse. However, they also indicate that the SCN plays a different role in comprehension and production.

Topic Areas: Meaning: Discourse and Pragmatics; Language Production

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Effects of semantic variables on processes during word planning for production: Evidence from electrophysiological data

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Semantic and lexical processing for word production are influenced by word-specific properties of the target word. A subgroup of these word properties are semantic variables, like the number of semantic features. A growing number of studies has investigated influences of semantic variables on behavioural measures of word production. For example, naming performance is facilitated by a higher number of semantic features and inhibited by higher intercorrelational density of a target word (e.g., Rabovsky et al., 2016, Cognition). Studying effects of semantic variables is an important area of research as it informs our understanding of both information representation and processing during word production. However, only one previous study has examined the influence of semantic variables on electrophysiological data collected during word planning for production in picture naming: Rabovsky et al., (2021, JEP:LMC) who analysed just two variables. By analysing electrophysiological data in addition to behavioural data for additional semantic variables, we aimed to further investigate how these variables influence processes during word production and work towards a better understanding of the brain correlates underlying behaviour and the temporal development of processes in word production. 78 participants named 291 colour photographs, while electrophysiological data were recorded. We investigated the electrophysiological correlates of six feature-based semantic variables: number of semantic features, intercorrelational density, number of near semantic neighbours, semantic similarity, typicality, and distinctiveness. The data were analysed using linear mixed effect models, including all six semantic variables, while also controlling for several psycholinguistic variables known to affect word production. We first replicated the analysis approach of Rabovsky et al. (2021), by analysing the mean amplitude of the event-related potential data in a posterior region between 200 and 550ms post picture onset and by investigating the development of the effects of the semantic variables across 10ms time segments between 0 and 550ms in a time-course analysis. Then, we conducted a microstate analysis to study whether, and, if so, how the semantic variables affected the durations of periods of stable electrophysiological patterns. Preliminary results suggest that most of the semantic variables influence brain activity during planning for production. So far, we find a stronger posterior positivity for words with more semantic features. Moreover, number of semantic features, intercorrelational density, semantic similarity, and number of near semantic neighbours affected the number of timeframes associated with two microstates. The results of the final analyses will be presented at the conference. These preliminary findings can be interpreted as reflecting increased activity in the semantic and lexical network involved in word production. This could reflect either enhanced activation of the target word itself or increased activation distributed across a cohort of co-activated semantically related lexical representations caused by the significant semantic variables.

Topic Areas: Language Production; Meaning: Lexical Semantics

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Alpha and high-gamma oscillations support the interface between language prediction and speakers' communicative intentions in spoken-language comprehension

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The present study investigated whether predictions during spoken language comprehension are supported by alpha and high-gamma oscillations. High-gamma oscillations are usually assumed to reflect prediction errors (Lewis and Bastiaansen, 2015), whereas alpha-band oscillations are closely linked to the main fundamental function of attention (Klimesch, 2012). Attention is particularly critical for successful language comprehension and construction of sentence meaning (Boudewyn, & Carter, 2018) and speakers' communicative intentions play an important role for the interpretation of sentence meaning. In line with previous studies showing that prediction shifts the attention to the expected event (Foxe et al., 1998; Mayer et al., 2016), we hypothesized a reduced power of alpha activity when the properties of incoming information were in line with those of predicted word in order to reinforce the initial interpretation of sentence meaning. Moreover, we expected to observe a higher decrease of alpha activity for the expected information when the communicative intentions of speakers provided a clear interpretation of the sentence. Differently, the power of high-gamma oscillations should be increased if an incoming information which was incongruent with the prior predictions and this effect should be enhanced by the communicative intentions of speakers. We conducted a first EEG experiment during which thirty-two French-speaking participants listened to semantically constraining sentences predicting a target word which was not presented. We focused on the power of alpha and high-gamma oscillations (respectively, 8-12 Hz, 60-100 Hz) associated with the article which could be either in agreement or in disagreement with the gender of the expected, yet not presented, word. The semantically constraining sentences were produced by the speaker with the intention of emphasizing the content of the sentence. We observed a reduced power of alpha-band oscillations when the gender of article was in agreement with that of the expected word and this pattern was found only when the speaker's communicative intention was strong. A second EEG experiment was conducted during which thirty-two participants had to judge the speaker's intention of communication in addition to listening and understanding the sentences. The stimuli were identical to those employed in the first experiment and the participants had the same characteristics as those included in the first experiment. The top-down attention focused on the speaker's intention of communication led to the removal of predictive effects on alpha-band oscillations. Interestingly, the power of high-gamma oscillations was however stronger for the expected gender than for the unexpected gender when the speaker's intention of communication was weak over a late time window. This suggested that prediction errors were elicited after the expected gender because of the expected, yet not presented and they were dependent on the speaker's intention of communication. The top-down attention focused on the speaker's intention of communication shaped frequency-specific brain dynamics supporting the interface between language prediction and speakers' communicative intentions. It thus appears that alpha and high-gamma oscillations play different attentional roles related to prediction in spoken language comprehension.

Topic Areas: Meaning: Discourse and Pragmatics; Prosody

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Licensing at the interfaces of syntax, semantics and pragmatics: Theta-band oscillations reflect low semantic value of discourse particles

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Linguistic licensing at the interfaces of syntax, semantics and pragmatics allows insights into the interplay of different components of grammar and their interactions with other cognitive systems like working memory during sentence comprehension. We present data from a series of experiments on the licensing of question-sensitive discourse particles (QDiPs) like German denn (lit. ‘then’). QDiPs must be licensed by a c-commanding [+Q(uestion)]-operator or wh-trace. They enrich the pragmatic impact of their surrounding clause type, and are subject to syntactic and semantic constraints, but have little semantic value of their own. We link findings from behavioral and ERP studies to an analysis of oscillatory brain activity for interface licensing of QDiPs in comparison to a non-QDiP baseline (the temporal adverb jetzt, ‘now’). In our stimuli, the QDiP denn occurred either (1) in the root clause of an interrogative (with accessible licenser; Wer hat den Kuchen aus der Bäckerei denn aufgegessen?, ‘Who QDiP ate the cake from the bakery?’), (2) in the embedded clause of an interrogative (with inaccessible licenser; *Wer hat gesagt, dass die Oma den Kuchen denn aufessen muss?, ‘Who said that the granny should QDiP eat the cake?’), or (3) in root or embedded clauses of a declarative (without licenser; *Robert hat den Kuchen aus der Bäckerei denn aufgegessen., ‘Robert QDiP ate the cake from the bakery.’). Each condition was compared to a well-formed baseline condition containing the temporal adverb jetzt (‘now’) instead of denn. Denn without licenser (3) leads to a drop in acceptability ratings and an enhanced P600 effect. Denn with inaccesible licenser (2) leads to only a mild drop in acceptability, and an enhanced, albeit shorter P600 effect. This latter finding might reflect either an alternative pragmatic licensing pathway for denn, or a previously undescribed linguistic illusion. The oscillatory brain activity showed an increase in theta-band activity for jetzt relative to denn. Given the higher semantic value of the temporal adverb jetzt relative to the semantically weak QDiP denn, this supports previous observations that the integration of the words with little semantic value or closed class words does not result in theta increase. At the same time, licensing violations eliciting P600 in ERP analysis did not lead to increases in theta-band activity. As theta-band activity is also linked to the processing of semantic and syntactic violations, memory-retrieval operations and working-memory load, our findings suggest that neither purely syntactic or semantic violations nor memory-retrieval costs play a major role in detecting QDiP licensing violations. Results also fit behavioral findings suggesting that unexpectedly good ratings for denn with inaccessible licensers (2) reflect alternative pragmatic licensing strategies, rather than a linguistic illusion involving memory-retrieval errors. In sum, our results support interpretations of oscillatory theta band activity reflecting semantic value differences. They also support behavioral findings against a prominent role of memory-retrieval errors during the QDiPs licensing and suggest that less-than-well-formed sentences can be interpreted thanks to alternative pragmatic licensing strategies. This contributes to our understanding of licensing at the interfaces of syntax, semantics and pragmatics.

Topic Areas: Meaning: Discourse and Pragmatics; Syntax

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Variation in how cognitive control modulates sentence processing

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Prior research suggests that cognitive control assists the comprehension of garden-path sentences that create conflict between interpretations. However, doubts remain about how cognitive control could influence a seemingly specialized and temporally tuned function like sentence processing. Our hypothesis tries to reconcile the two perspectives by proposing that cognitive control might influence (1) the online processing of sentences that require the integration of multiple conflicting cues but not other complex structures; (2) the offline decision processes related to choosing an interpretation and doing the experimental task. We also hypothesized that these effects could be modulated by individual differences in cognitive control. We found suggestive correlational evidence in six persons with aphasia: patients who showed large Stroop effects also showed slowed-down processing of sentences with multiple conflicting cues. We looked for additional causal evidence by testing healthy younger adults in a “conflict modulation” paradigm. Methods: We measured word-by-word self-paced reading times and comprehension accuracy for three types of sentences in a web-based study (N=78 healthy adults aged 18-35 years). Within each type, we had congruent (sentence matches prior language and world experience) and incongruent (sentence violates expectations) conditions. (1) Syntax-Semantics: Congruent-During the filming, the actor was directed by the creative producer; Incongruent-During the first rehearsal, the conductor was directed by the creative musician (actors are usually directed, conductors usually direct) (2) Phrase-Attachment: Working at the valet stand, Colin said put the car (that’s) in the entrance into the parking lot and drive slowly (Congruent contains “that’s”, Incongruent does not) (3) Relative Clause: In the research institute, the technician (Congruent=who contacted the lab manager; Incongruent=who the lab manager contacted) was analyzing the biological samples. Sentences were interleaved with Stroop trials. A given sentence could follow a congruent (e.g., “blue” in blue font) or incongruent (e.g., “orange” in blue font) Stroop trial. A 2x2 conflict modulation design (Stroop congruence x Sentence congruence) tested whether a previous Stroop trial affected the processing of a subsequent sentence. On a separate day, participants completed cognitive control (Stroop, AXCPT, Flanker) and working memory (reading, operation, and backwards digit spans) tasks. Results: Exploratory factor analysis confirmed the separability of individuals’ cognitive control and working memory abilities. Cognitive control predicted (1) online conflict modulation at specific disambiguation points for syntax-semantics (by: $t=-2.2$, $p=.03$; the: $t=2.1$, $p=.04$) but not other sentence types; and (2) offline comprehension accuracy for syntax-semantics ($t=-1.8$, $p=.07$) and phrase-attachment ($t=-4.5$, $p<.001$) but not relative clause sentences. In contrast, working memory predicted (3) offline comprehension accuracy for relative clause sentences ($t=3.2$, $p=.002$). Conclusions: Together, the results show that the effect of cognitive control on online and offline sentence comprehension is modulated by both the type of sentence/conflict and individual differences in cognitive control ability. We suggest that the theoretical controversy regarding the conflict modulation effect could be resolved by better understanding variability. Clinically, this perspective has ramifications for characterizing and treating different individuals with aphasia.

Topic Areas: Syntax; Control, Selection, and Executive Processes

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Characterization of Heschl's Gyrus subtypes using Morphology-Encoding Graphs

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Heschl's Gyrus (HG) is the first cortical structure to receive auditory input. The most common HG gyrification patterns include single gyri, Common Stem Duplication (CSDs) and Complete Posterior Duplications (CPDs). Previous work has shown both greater HG volume and gyrification in relation to musical (Benner et al., 2017) and phonetic expertise (Golestani, Price, & Scott, 2011), and also volume and gyrification differences in dyslexia (Altarelli et al., 2014; Serrallach et al., 2016). Conventional structural measures such as gray matter volume, surface area and cortical thickness are complementary to indices of HG shape. These conventional measures are mostly obtained using visual assessment and manual labeling (Benner et al., 2017), but the recently developed TASH toolbox (Dalboni da Rocha et al., 2020) allows fully automated labeling of HG from T1 structural MRI images, and extraction of such measures. We present a method for characterizing the morphology of HG using unweighted, undirected surface-based and volumetric graphs. HG labels were produced using TASH, and used to extract both conventional anatomical features but also spectral graph features. We validated how well spectral graph features discriminate between single HG versus CSDs (as determined visually by an experienced rater) compared to that possible by using conventional anatomical measures (i.e. volume, surface area and thickness) alone. We used data from 177 adults, including non-musicians, amateur and professional musicians. For the surface-based HG graph, vertices and edges of the HG labels on the white matter surface readily provided the desired graph representation. We also created 1mm3 and 0.6mm3 resolution volume-based graphs by transforming the labels to cortical volumes; voxels within cerebral cortex were treated as graph nodes, and edges were defined based on 26-neighborhood connectivity between adjacent voxels in 3D space. For each graph, we computed the graph's normalized Laplacian matrix, and consequently, obtained the graph's Laplacian spectrum by performing eigendecomposition on the matrix (for details, see (Maghsadhagh, Eklund, & Behjat, 2019)). The following spectral features were then extracted: a) an initial subset of the lower eigenvalues (excluding 0), b) the largest eigenvalue, c) distribution of eigenvalues across the spectrum, d) the area under the curve of the cumulative sum function of eigenvalues and e) normalized Laplacian energy of the graph. Discrimination of HG subtypes against visually determined categories (single vs CSD) was done using: 1) conventional anatomical measures, 2) spectral features, and 3) conventional measures together with spectral features. Results reveal substantially better discrimination performance using spectral features compared to when using conventional measures alone. The first ten eigenvalues were the most informative spectral graph feature among those that were tested. In future work, we anticipate that the proposed spectral features be found beneficial for systematic exploration of variations in HG typology in relation to cognition and disorder in the context of healthy language and music related variability, expertise and disorder. Furthermore, we aim to extend the graph definition to a weighed graph by using local measures such as cortical thickness, to further improve discriminative power of the proposed class of spectral shape features.

Topic Areas: Computational Approaches; Morphology

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The P600, but not the N400, is modulated by sustained attention

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There are two prominent language related ERP components, the N400 and P600 component, and it's still debated how exactly they differ in terms of underlying processes during sentence comprehension. It has recently been suggested that one important dimension along which these components vary is in terms of automaticity versus attentional control, with N400 amplitudes reflecting more automatic and P600 amplitudes reflecting more attention dependent aspects of sentence comprehension (Rabovsky & McClelland, 2020, Phil. Trans. B.). Indeed, the P600 correlates with indicators of executive function (Brothers et al., 2021, biorxiv) and is reduced or absent when the task does not require participants to process linguistic anomalies while N400 effects are less task dependent (Schacht et al., 2014, PLoS One). However, besides the direct manipulation of task relevance, more evidence on the role of attention for P600 and N400 amplitudes is still scarce. Generally, the availability of executive resources depends on the degree of sustained attention, which fluctuates over time (Esterman & Rothlein, 2019, Curr Opin Psychol). Thus, if the P600 indeed reflects a controlled process, it should be reduced when sustained attention is low, and thus, less of the necessary executive resources are available. On the other hand, if the N400 indeed reflects an automatic process, its amplitude should not depend on sustained attention. Here, we tested these predictions with a sentence processing paradigm using reaction time variability as an index of sustained attention. We re-analysed EEG and behavioral data from a visual sentence processing task by Sassenhagen & Bornkessel-Schlesewsky (2015, Cortex). Half of the German sentences were correct (Lit: 'To the category fruit belong the pear, the apple, and the mango'). ¼ of the sentences contained a mismatching determiner (morphosyntactic violation) and further ¼ of the sentences contained a hyponym which belonged to a different semantic category (semantic violation). Participants read sentences phrase by phrase and indicated whether a sentence contained any type of anomaly as soon as they had the relevant information. To quantify periods of high versus low sustained attention, we extracted a moving reaction time coefficient of variation over the entire course of the task for each participant (see e.g., Van den Brink et al., 2016, PLoS One). P600 amplitude was significantly larger during periods of low reaction time variability (high sustained attention) than in periods of high reaction time variability (low sustained attention), even when controlling for individual trial reaction time ($\beta = 0.767$, $SE = 0.322$, $t = 2.376$, $\chi2 = 5.64$, $p = .017$). In contrast, the amplitude of the N400 was not affected by reaction time variability ($\beta = 0.38$, $SE = 0.28$, $t = 1.36$, $\chi2 = 1.85$, $p = .174$). These results thus suggest that the P600 component is sensitive to the current degree of sustained attention while the N400 component is not, which is in line with the idea that P600 amplitudes reflect more controlled and N400 amplitudes more automatic aspects of sentence comprehension (Rabovsky & McClelland, 2020).

Topic Areas: Control, Selection, and Executive Processes; Syntax

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Semantic conflict is resolved by semantic and multiple demand networks

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How do our brains deal with irrelevant information? Neuroimaging studies show that a variety of brain regions help to regulate meaning processing so that only correct, relevant information is focused upon. The current study provides new information on which brain areas are active when dealing with irrelevant, conflicting information. Moreover, we elucidate how these regions interact—with one another and with other brain networks—to drive successful resolution of such conflict. Forty participants performed two semantic tasks in which they made yes/no judgments on simultaneously presented pairs of line drawings while undergoing fMRI. In the taxonomic task, they judged whether items were in the same category; in the thematic task, they judged whether items were associated thematically but not in the same category. Both tasks included the same items, which could be taxonomically related, thematically related, or unrelated. The semantic brain network for the tasks was investigated by contrasting performance across both semantic tasks with performance on a visual control task, in which participants judged whether two scrambled images were mirrored versions of each other. Regions dealing with semantic conflict were measured by comparing items that were related in a way that was irrelevant to the current task (e.g., thematically related items in the taxonomic task) compared to unrelated items across tasks. All fMRI statistical analyses were performed with GLMs in SPM 12. Results from semantic and conflict contrasts were thresholded at FWE-corrected $p < .05$. Regions from the tasks' semantic network were used as seed regions for effective connectivity (PPI) analyses, which were performed with the gPPI toolbox. One-sample t-tests were then performed on subject-level results and thresholded at $p < .001$, uncorrected. Our crucial PPI contrast was the semantic conflict contrast cited above. The observed semantic network included the bilateral angular gyrus (AG) and adjacent lateral occipital cortex, bilateral precuneus and posterior cingulate (PCC), left inferior frontal gyrus, left posterior middle temporal gyrus (pMTG), and left fusiform gyrus, extending medially. Regions more active in the conflict condition overlapped the semantic network in the bilateral AG, bilateral precuneus/PCC, and left pMTG and additionally included the bilateral medial superior frontal regions, left frontal pole, and right middle frontal gyrus. In PPI analyses, connectivity increased between ROIs from our tasks' semantic network (right AG, bilateral precuneus/PCC) and regions associated with multiple demand and semantic control networks in trials where items were related in an irrelevant way compared to when items were unrelated. Our results thus provide evidence that resolution of semantic conflict relies on domain-general and domain-specific functional brain networks. Interestingly, the seeds revealing these networks suggest a crucial role for bilateral multiple-demand regions in driving the resolution of semantic conflict, in contrast to the predominately left-lateralized semantic control network. Future planned analyses will reveal whether behavioral effects are impacted by the strength of our observed connectivity and whether resting-state connectivity in the same participants reveals the same semantic networks as our effective connectivity analyses.

Topic Areas: Control, Selection, and Executive Processes; Meaning: Lexical Semantics

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Relating specific dimensions within the home literacy environment to brain reading network structure in second-grade children

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Home literacy environment (HLE) has been shown to predict children's brain differences and reading performance. This study aimed to investigate the extent to which specific dimensions within the HLE are related to cortical thickness and reading abilities in N = 112 children after second grade (47% girls; m ages = 8.46). Children were assessed for their word recognition and reading comprehension abilities, as well as underwent T1-weighted MRI scans to evaluate the cortical thickness of their brain. Parents were asked to complete an extended HLE questionnaire, which consisted of items from previous parent-rating surveys and behavioral studies. Children's demographic variables (age, sex, handedness, and school information) and parents' self-report data (educational attainment and reading history) were included as covariates. Exploratory factor analyses on the extended HLE questionnaire revealed three dimensions: formal activities, such as teaching to read and shared reading; informal activities, including conversational exchange and parent-child communication; and child-initiated activities. Analyses with brain indices showed that the HLE composite scores were related to increased cortical thickness in the brain reading network and prefrontal regions, which in turn explained better reading abilities. Follow-up analyses suggested that specific HLE dimensions mapped onto these regions differently to predict children's reading abilities: formal activities were related to the inferior frontal, ventrolateral prefrontal, and superior temporal cortices; informal activities were linked to the ventral lateral prefrontal cortex; and child-activities were associated with the dorsolateral prefrontal and superior temporal cortices. These results implicate different brain mechanisms in which specific dimensions within the HLE contribute to children's reading outcomes.

Topic Areas: Reading; Control, Selection, and Executive Processes

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Resting-state connectivity and functional activation during reading in persons with alexia

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Reading is essential for independence and activities of daily living. After stroke, between 68-80% of persons with aphasia have an acquired reading disability, or alexia (Benjamin et al., 2018, Brookshire et al., 2013). While there is much functional imaging research examining neural circuitry in persons with aphasia, very little research, outside of case studies, has been performed to understand those neural mechanisms used by persons with acquired reading deficits after stroke. In this project, we aimed to understand the altered or compensatory neural networks underlying reading in adults with aphasia. Here we present pilot data of 4 persons with alexia (M/F: 2/2, Age: 65 ± 16) who underwent resting state and task-based imaging in a Siemens 3T Prisma MRI Scanner. 3 participants had mild anomic aphasia and 1 participant had moderate conduction aphasia (WAB: 82 ± 8.3). All participants had mild to moderate reading impairment: Test of Word Reading Efficiency-2 (74 ± 11.4). Participants underwent imaging at rest and also performed the Fast fMRI Localizer Task (Fast-Loc) in the scanner (Malins et al., 2016). This task has been shown to be highly effective at identifying brain regions that are sensitive to the linguistic properties of reading, specifically lexicality, spelling-sound consistency, and semantic similarity. We performed standard preprocessing and processing with in-house pipelines using AFNI and FSL. Resting state data were analyzed with seeds in right and left hemisphere supramarginal gyrus. Resulting connectivity (p<1-12, cluster size>50) were analyzed within subject. Patients with more severe reading impairment had greater connectivity within reading and language areas and homologous areas within the left and the right hemisphere. Participants with less severe reading impairment had less connectivity between left hemisphere reading areas and right hemisphere SMG. Left hemisphere connectivity was greatest in patients with less severe reading impairment while participants with more severe reading impairment had decreased connectivity in left hemisphere. Further analysis of task-based activation in two of these participants were performed with t-tests of semantically related words and phonologically related words against a false font condition (p<0.001, cluster size > 50). While reading semantically related words, the participant with more mild alexia showed a pattern of dorsal stream activation and involvement of right hemisphere ventral stream areas and the participant with more severe alexia showed a pattern of dorsal stream activation as well as right hemisphere activation in superior and middle temporal gyrus. While reading phonologically related words, both participants showed a pattern of incomplete left hemisphere dorsal stream activation with decreased or no activation in the right hemisphere. The relationship between resting state connectivity in reading areas and task-based activation during reading in persons with alexia warrants further exploration. The increased RH connectivity in participants with more severe alexia could be important for understanding why some persons with alexia have greater reading impairment in the chronic stage post-stroke. Further understanding this relationship is important for determining target sites for non-invasive brain stimulation to improve reading abilities for persons post-stroke.

Topic Areas: Reading; Disorders: Acquired

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The involvement of bilateral supramarginal gyrus in orthographic processing during Braille reading

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Learning to read leads to cortical specialization for orthographic representations of letters, letter combinations, and words. An outstanding question is whether the sensory modality of reading (visual print vs. tactile Braille) influences its neural basis. According to the task-based hypothesis, visual and tactile reading depend on the same visual word form area (VWFA) mechanism within the ventral occipitotemporal cortex (vOTC) (Amedi, Hofsetter, Maidenbaum et al., 2017; Heimler, Behor, Dehaene et al., 2015). On the other hand, based on the connectivity hypothesis, we predicted that Braille reading would recruit regions of posterior parietal cortex that are connected to both the somatosensory and language networks (Saygin, Osher, Norton et al., 2016; Li, Osher, Hansen et al., 2019). To distinguish between these hypotheses, twelve congenitally blind fluent Braille readers were recruited for functional MRI scans, during which they read real words and pseudowords on a Braille display. Participants were asked to press one button if the word was a pseudoword, a second button if it was an animate real word and a third button if it was an inanimate real word. The task ensured attention to both the form and the meaning of the words. All stimuli consisted of four Braille cells (e.g., ⠉⠕⠗⠝ [corn]) and were presented in Grade 2 Universal English Braille (UEB). Grade 2 UEB contains "contractions", such that one Braille cell may stand for more than one letters (e.g., ⠜ [ar]; ⠬ [ing]). This enabled us to study the effects of letter length on neural activity, independent of the physical length of the stimuli (e.g., ⠎⠥⠛⠜ [sugar]; ⠒⠉⠻⠞ [concert]). We also tested which cortical areas distinguish between real words and pseudowords based on univariate and multivariate responses (MVPA). Parietal cortex showed several signatures of orthographic sensitivity. First, a whole-brain univariate correlational analysis revealed a positive effect of letter length of real words in bilateral parietal cortex (anterior supramarginal gyrus, SMG) and prefrontal cortex. Crucially this letter length effect in contracted Braille is independent of physical word length and is therefore unlikely to reflect low level tactile responses. Second, similar parietal SMG areas responded more to pseudo words than real words in univariate analysis. By contrast, larger univariate responses to words were observed in classical semantic areas, including the bilateral precuneus and bilateral angular gyri (AG). Finally, multivariate activity patterns in parietal/parieto-occipital regions distinguished between words and pseudowords. Larger responses to psuedowords were also observed in medial vOTC but not lateral. The present results suggest that fronto-parietal cortices, specifically the SMG, may become specialized for form-based orthographic processing of Braille. Our findings do not rule out the possibility that vOTC contributes to Braille reading, however, they suggest that tactile reading of Braille relies on partially distinct neural mechanisms as compared to visual print.

Topic Areas: Reading; Disorders: Developmental

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The topological properties of the left thalamus in the white matter network in children with reading disabilities

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MRI studies of reading disabilities (RD) report anomalies in white matter tracts between the left thalamus and primary sensory cortex (Müller-Axt et al., 2017; Tschentscher et al., 2019), suggesting a potential role of thalamo-cortical connections in RD. In addition, recent studies report deficits of white matter tracts at the connectome level in RD (Bathelt et al., 2018; Lou et al., 2019, 2021; Lee et al., 2020). However, little is known about how the left thalamus and thalamo-cortical connections in the connectome affect reading performance. Here we investigated whether thalamo-cortical networks are related to reading performance in children with RD. 64 children (ages 8 -14 years, 31 boys) underwent diffusion-weighted imaging at 3T and were tested on a series of reading tasks including sight word reading, phonemic decoding, reading comprehension, and rapid automatized naming. The sample ranged in reading ability and included a subset of children with identified RD. Each participant's whole-brain network was constructed, with number of streamlines, determined via whole-brain tractography, used as edge weights connecting 90 parcels. The topological properties of the left thalamus, including efficiency and routing cost (Avena-Koenigsberger et al., 2019), were computed based on both the whole-brain network and a subnetwork which was composed of connectome hubs and reading network nodes. Efficiency was evaluated by local efficiency (LE) and clustering coefficient (CC), and routing cost was evaluated by informational cost (IC) and transmission cost (TC). In addition, the number of streamlines between the left thalamus and all reading network regions per edge, as well as two reading-related regions (superior temporal gyrus, STG, and middle temporal gyrus, MTG) were extracted. Partial correlations were correlated between reading scores and topological metrics of the whole-brain network and the subnetwork, with gender and handedness as covariates. Another analysis examined whether the number of streamlines between the left thalamus and reading-related regions (STG, MTG, and all reading network regions) were associated with reading scores. Family-wise error was corrected with a 10,000-permutation Monte-Carlo simulation. Significant correlations between topological metrics of the left thalamus and reading scores were observed only in the subnetwork. CC ($r = -.35$, $p(corr) = .019$) and LE ($r = -.40$, $p(corr) = .006$) were correlated with reading comprehension. Similarly, CC ($r = -.34$, $p(corr) = .025$) and LE ($r = -.32$, $p(corr) = .043$) were correlated with rapid automatized naming. TC was positively correlated with phonemic decoding ($r = .36$, $p(corr) = .021$). In addition, the average number of streamlines between the left thalamus and reading network was correlated with reading comprehension ($r = -.31$, $p(corr) = .045$), and the number of streamlines between the left thalamus and left STG was correlated with phonemic decoding ($r = -.35$, $p(corr) = .020$). A control analysis of the right thalamus yielded no significant correlations. The present study demonstrated that reading subskills were associated with thalamo-cortical connections and topological properties of the left thalamus in the white matter network. This work highlights the role of the left thalamus and thalamo-cortical network in understanding skilled and impaired reading in children.

Topic Areas: Reading; Disorders: Developmental

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The effect of COMT on reading is mediated by top-down fronto-striatal activation.

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Introduction: The COMT gene codes for the Catechol-O-methyltransferase enzyme, which metabolizes released dopamine in the prefrontal cortex and is a strong regulator of prefrontal dopamine levels. Variation at codon 158 of the COMT gene results in a valine (Val)-to-methionine (Met) substitution, which has been associated with functional alterations within the prefrontal cortex, and impacting several prefrontally mediated cognitive functions and neurodevelopmental disorder susceptibility. Recently, our group found that the COMT Val158Met polymorphism was associated with reading-related skills, specifically phonological awareness, spelling and reading comprehension [1]. We also showed that the polymorphism was related to functional neural activation during reading in a number of reading-related regions. These findings implicated COMT as a possible risk gene for reading disability (RD). Here, we hypothesize the pathway from gene to reading is mediated by intermediate phenotypes (IPs), specifically brain activation and PA. Methods: We conducted a serial multiple mediation model in a sample of 97 children (age 5–13) using genotype groups (i.e. Val/Val, Val/Met, Met/Met) as predictors, brain activation and phonological processing (PP) as serial multiple mediators, and reading as outcome. The model was tested on a set of 6 ROIs where we previously saw activation differences during reading as a function of genotype group, these include: the right middle frontal gyrus (rMFG), left temporal pole, right precentral gyrus, left inferior frontal gyrus, left parahippocampal gyrus, and left inferior frontal gyrus/insula. PP and reading were obtained by a PCA with letter-word identification, pseudoword reading, spelling, passage comprehension, blending words, memory for digits, non-word repetition, blending non-words, reading sight words, and decoding non-words, as variables. Indirect effects from COMT Val158Met polymorphism to reading via brain activation and PP were tested by using Structural Equation Modelling. We controlled for the effect of age on both behavioral scores (i.e., PP and reading) and brain activation. Results: There was no significant combined indirect effect from COMT Val158Met polymorphism to reading via brain activation and PP jointly. However, there was a specific indirect effect of the COMT-Val158Met polymorphism to reading via brain activation in the rMFG (Met/Met vs. Val/Met: β=-0.167, SE=0.088, 95% CI=-0.367/-0.014; and Met/Met vs. Val/Val: β=-0.177, SE=0.097, 95% CI=-0.390/-0.013). Specifically, both the Val/Met and Val/Val genotype groups had lower activation relative to the Met/Met group in rMFG, and brain activation in this ROI was positively related to reading. The combined indirect effect of Val/Met and Val/Val genotype groups to reading via activation in rMFG was significant (β=-0.344, SE=0.178, 95% CI=-0.732/-0.029). The mediation model for the rMFG explained on average 25% of the reading variance. Conclusion: These findings suggest that the COMT Val158Met polymorphism is related to reading via top-down cognitive influences connected to the activity in fronto-striatal networks rather than via PP. We note that these findings are preliminary due to relatively low power (small sample size for genetic and mediation analyses), and require replication. Other relevant behavioral/cognitive abilities (e.g. working memory and executive functions) remain to be explicitly tested in future studies.
References [1] doi: 10.1111/j.1467-7687.2012.01180.x.

Topic Areas: Reading; Language Genetics

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Non-invasive auricular vagus nerve stimulation improves memory for read passage content in young adults

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Expert reading acquisition is marked by fluent, effortless decoding and adequate comprehension skills and is required for modern daily life. In spite of its importance, many individuals struggle with reading comprehension even when decoding skills are adequate. Unfortunately, effective reading comprehension interventions are limited, especially for adults. A growing body of research suggests that non-invasive transcutaneous stimulation of the auricular vagus nerve (taVNS) may drive neural plasticity for low-level reading skills such as speech sound perception and letter-sound learning, but it is unknown whether taVNS can improve higher level skills as well. Thus, the current study was designed to evaluate whether taVNS paired with passage reading can improve reading comprehension performance. Twenty-four typically developing young adults were recruited and screened for baseline reading and working memory skills. Participants received either sham or active 5 Hz taVNS while reading short passages out loud. Immediately following each passage, stimulation was turned off in the active group and all participants answered a series of test questions that required either direct recall of passage details or more complete comprehension of the passage content. While taVNS did not improve the mechanics of reading (e.g., reading rate or accuracy), there was a significant benefit of active taVNS on test questions. This effect was driven by significant improvement on accuracy for memory questions while there was no effect of taVNS on comprehension question accuracy. These findings suggest that taVNS may be beneficial for enhancing memory, but its efficacy may be limited in higher cognitive domains. I will discuss these findings as well as some ongoing work in our lab designed to probe the conditions under which taVNS is effective.

Topic Areas: Reading; Methods

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Parental education is correlated with children's reading but not rhythm perception skills

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Although reading is a critical skill in the modern world, a significant proportion of individuals fail to reach fluency. There are several well-studied risk factors for reading disability. Biological risk factors, such as dyslexia-susceptibility genes, are thought to impact reading by altering brain development, while environmental risk factors, such as socioeconomic status (SES) have a multi-faceted impact on reading. Children of highly educated parents often experience higher-quality linguistic stimulation, which facilitates literacy and may also impact neural connections. One aspect of SES, Parental education (PE), has been associated with increased baseline cognitive abilities in children, further supporting the importance of this early environmental influence. In addition, there has recently been increased interest in other cognitive factors that may subserve reading. For example, a growing body of evidence suggests a relationship between reading and rhythm perception. However, it is currently unknown how these variables influence each other and whether baseline cognitive abilities, such as rhythm perception, could influence the impact of PE on reading. In the current study, we recruited 68 children (age 9.89 ± 1.46) and collected data in a fully virtual format during the COVID-19 pandemic. Children completed an assessment session as well as several online activities at their own pace, including a rhythm matching task, while parents completed a family member's background survey. We were able to replicate prior studies reporting significant correlations between reading skills and PE, and partially replicated prior findings of a relationship between reading skills and rhythm matching skills. However, we found no correlation between rhythm matching and PE. We utilized partial correlations using rhythm as a covariate and found that rhythm did not mediate the relationship between PE and reading. Finally, there was a significant positive correlation between rhythm processing and age. While we did not quantify music training, this finding was expected given that most children in the US receive at least some mandatory music training as they leave elementary school, which should improve their performance in rhythm perception. Our results support prior work suggesting that while PE is significantly correlated with reading outcomes in young children, PE may not influence rhythm perception in a similar way. These findings suggest PE may be critical for the acquisition of reading but not rhythm skills in children. If these results are confirmed, they may provide support for early music and rhythm training to improve literacy outcomes in children from lower SES homes.

Topic Areas: Reading; Perception: Auditory

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Spatiotemporal brain dynamics of sentence reading

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Reading a sentence entails inferring meaning from combinations of multiple lexical objects that are combined into phrases and sentences, allowing us to derive complex meaning. Studies of cortical activity underlying semantic and syntactic operations implicate inferior frontal gyrus (IFG) and middle temporal gyrus (MTG), yet the relative contributions of these regions to sentence comprehension remain controversial. We used direct intracranial recordings from the IFG and MTG in the left, language-dominant hemisphere within a large cohort to map the spatiotemporal neural correlates of multi-word semantics and sentence structure building. 29 patients undergoing semi-chronic implantation of intracranial electrodes for localising pharmaco-resistant epilepsy silently read sets of Sentences, Jabberwocky sentences, Unstructured word lists, and Pseudoword lists, all 8 words long and presented in rapid serial visual presentation. Broadband gamma activity (70-150Hz) was extracted from electrodes across the left hemisphere (n>2,500) and subjected to linear mixed effects modelling to dissociate the impact of sentence structure, word frequency and lexicality on the recorded activations. Contrary to predictions from prior studies, we found that sentence structure did not lead to a simple monotonic increase in activation across the duration of the sentence, relative to word lists. Instead, we observed an initial suppression of activity for sentences, coinciding with the formation of a minimal phrase structure at word 2, followed then by a progressive increase in activity along the remaining duration of the sentence. This pattern was identical for electrodes in MTG, anterior IFG and medial frontal operculum. Ventral visual cortex, parietal cortex and posterior IFG did not show modulation by sentence structure. Jabberwocky sentences and pseudoword lists did not display systematic differences related to sentence construction in any region. Lastly, a tuning to word frequency was observed broadly across ventral occipitotemporal cortex, appearing earliest in mid-fusiform cortex, and preceding frequency tuned responses in IFG and traditional visual word form regions by around 200 ms. Our work suggests that the neural correlates of sentence structure comprehension primarily care about an accumulation of semantic rather than syntactic information. Both IFG and MTG demonstrate comparable sensitivity to sentence structure. The IFG is sensitive to lexical properties of single words, subserving an item-specific representation, while MTG appears to be involved in the generation of abstract, structural inferences. We also demonstrate a three-way functional dissociation of lexical and sentence level sensitivity within the frontal lobe, between anterior and posterior lateral IFG and the medial frontal operculum. Our work provides crucial insight into the integration of individual words into complex semantic concepts and highlights the critical need for large cohort studies of sentence processing utilising methods that provide high spatiotemporal resolution.

Topic Areas: Reading; Syntax

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Examination of the Functional Specificity of the Visual Word Form Area (VWFA) and the Intraparietal Sulcus (IPS) in Atypical Reading and Math: A Meta-Analysis

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Introduction: The literature largely supports the specificity of Visual Word Form Area (VWFA) to proficiently identify words during reading (e.g., Cohen et al., 2000) and the Intraparietal Sulcus (IPS) to adequately process numbers during math (e.g., Arsalidou & Taylor, 2010). Yet, it remains unclear whether these areas play a role across other types of tasks, in individuals with learning difficulties. The purpose of this study is to identify consistencies across studies regarding the functional specificity of VWFA for individuals with reading disabilities (RD) and the IPS for individuals with math disabilities (MD), compared to typically developing individuals (TD) individuals. Methods: A systematic search of the literature, utilizing multiple databases, identified 4,505 research items. Items including journal articles, dissertations, and conference proceedings were hand-sorted, using article titles. 557 items were then closely read to determine eligibility, employing the following criteria: 1) represented original research; 2) included at least one measure of functional whole brain imaging; and 3) included at least one group of participants identified with RD or MD. A hand search was also conducted and resulted in the addition of 97 articles for review. This process yielded 118 studies that were double coded. Coordinates that directly compared TD with RD or MD were entered into GingerALE (Brainmap.org). An activation likelihood estimate (ALE) meta-analyses was conducted to examine the specificity of the VWFA and the IPS across studies. The VWFA was defined as a sphere centered at (x = -44, y = -58, z = -15) with a radius equal to 5mm (Jobard et al., 2003; Vigneau et al., 2005) and the IPS was centered at (x = 36, y = -48, z = 48) with a 5mm radius (Sokolowski et al., 2017). Imaging results are reported using a family wise error (FWE) correction of $p < .05$. Results: Overall, there were more studies that examined RD (n=98) than MD (n=20). The RD studies sampled elementary students to adults; however, the majority of the MD studies included elementary students and included no high school students. Under activation of the VWFA was corroborated in studies that examined children and adults with RD across reading tasks (i.e., reading aloud, rhyming, lexical decision), oral language tasks (e.g., picture naming, picture rhyming task), and other types of tasks (i.e., passive visual motion, motion detection). Overactivation of the IPS was demonstrated in studies that examined children with MD across math tasks (e.g., math facts, calculation, magnitude comparison) and other types of tasks (spatial working memory, reasoning). Conclusion: Preliminary results indicate that the functional activation VWFA was not specific to reading tasks for individuals with RD and the IPS was not exclusive to math tasks for individuals with MD. Instead, the VWFA also exhibited under activation across oral language and motion-related task in children and adults with RD. For children with MD, over activation of the IPS was also displayed in working memory and reasoning tasks. These findings suggest that the functional specificity of the VWFA and the IPS are broadly anomalous for individuals with learning disabilities.

Topic Areas: Disorders: Developmental; Reading

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Neural Activation during Phonological Processing in Primary-School Children with Limited Reading Experience: Insights from Rural Côte d'Ivoire

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Introduction: Phonological awareness (PA), the ability to recognize and manipulate language sounds, is both an important predictor and outcome of reading skill. With more reading experience, PA improves, and left-hemisphere (LH) temporo-parietal regions (e.g., LSTG) that support phonological processing become increasingly engaged during both speech and reading. However, little is known about the reciprocal relation between PA and reading across development in the absence of consistent reading experience. Individuals who did not learn to read (i.e. illiterate adults) show poorer PA relative to their literate peers. Individuals who learn to read in adulthood struggle to achieve fluency, suggesting that reading experience in childhood, a period of greater brain plasticity and sensitivity to phonological information, best supports the reciprocal development of PA and reading. Here, we ask how neural activation patterns in the left temporo-parietal cortex during phonological processing relate to reading skills in children with little reading experience. We focus on rural Côte d'Ivoire, where children have inconsistent reading experience (i.e due to starting school at an older age and poor access to quality education). We hypothesize that activation in the left temporo-parietal cortex during phonological processing corresponds to children's reading experience and reading skills. Methods: Sixty-nine children (7-13 years, Mage=10.4, SDage=1.53) completed a French rhyme judgment task while undergoing fNIRS neuroimaging, and a French letter, word, and pseudoword reading task. The rhyme judgment task (a measure of PA) required children to listen to randomly-presented word pairs, and determine whether the word pair rhymed or not. We used AnalyzIR toolbox to estimate the effects of rhyming vs. non-rhyming word pairs, reading skill, and their interaction in the prefrontal and bilateral temporo-parietal cortices with a linear mixed effects model. Behavioral Results: Children's accuracy was above chance for rhyme judgement, and higher for non-rhyming versus rhyming word pairs. Children's reaction time was not significantly influenced by condition. Overall, reading skill levels were very low. Neuroimaging Results: We found a significant main effect of reading skill; higher reading scores were associated with greater activation mainly in the left temporo-parietal cortex. Importantly, we found a significant interaction between rhyming condition and reading skill. Neural activation in bilateral temporal cortex (BA21/40/48) was greater for non-rhyming words versus rhyming words for children at all reading skill levels. However, children with lower reading scores (i.e., 1SD below mean) showed greater activation in the IFG and DLPFC (BA10/45/46) for non-rhyming versus rhyming word pairs. Conclusion: Our results support our hypothesis; greater activation in the left temporo-parietal cortex was associated with better reading skills. However, we found that phonological processing is supported by additional prefrontal regions in less-skilled readers, suggesting that additional cognitive resources may support phonological processing. Our findings suggest that in the absence of consistent access to quality education, children with limited reading experience may 'miss out' on the reciprocal interaction between phonological processing and reading, which in turn shapes how language is processed in the brain.

Topic Areas: Language Production; Reading

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Lexical neighbors support stronger decoding than non-word neighbors: Implications for the neural representation of words

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Introduction: Neural decoding research has shown that cortical regions of the superior temporal gyrus are selectively sensitive to phonetic features. It is less clear how this segment-level input is bound into representations of wordform associated with downstream structures including the posterior middle temporal gyrus (pMTG) and temporal poles. Evidence for lexical neighborhood effects in spoken word recognition suggest that overlapping words partially activate multiple lexical candidates that actively compete. Such activation is consistent with either graded holistic or discrete compositional activation. Discriminating between these alternatives will provide insight into diverse phenomena including nonword lexical similarity effects, the perception of coarticulated speech, constraints on phonotactic structure, form priming and lexical competition effects. We hypothesize that classifiers trained to distinguish between lexical neighbors of two words (e.g. pig and toad) should also be able to distinguish those words without additional training. If lexical representation is holistic, non-words would not produce similar transfer learning. On the other hand, if lexical representation is compositional (e.g. segments or bigrams) training on nonword neighbors of the same words should also show similar transfer because those items will activate the same components as lexical neighbors do. Aim: To determine whether word level representation is holistic or compositional. Methods: The stimuli consisted of spoken CVC words and nonwords. Six hub words were chosen to define lexical neighborhoods. For each hub, we created 3 word and 3 nonword neighbors by changing only one phoneme, with the position of the changed phoneme counterbalanced across the 3 potential positions. For example, for the hub word pig we identified the lexical neighbors big, peg and pick and the nonword neighbors tig, poog and pid. Training and testing were done with 8 different talkers (4 male and 4 female). Simultaneous MEG/EEG data were collected (with structural MRI in a separate session) from 12 native English speakers while they complete an auditory lexical decision task. Three language-related ROIs (supramarginal gyrus, pMTG, temporal pole) and two control ROIs were created for each individual participant. Decoding was done based on each individual subject’s ROI source time courses using support vector machines (SVM). SVMs were trained to discriminate neighborhoods using trials when neighbors were presented then tested on untrained hub words to measure if transfer learning occurred. The pairwise classification analyses were repeated with different sets of neighbors. Separate analyses were done using only word or nonword neighbors, respectively, for training to examine the effect of lexicality. Results and Conclusion: SVMs successfully discriminated hub words after training on word neighborhoods with pMTG and temporal pole, but not with control region activation timeseries. However, training on nonword neighbors resulted in poorer classification. These results are consistent with the predictions of the holistic wordform representation hypothesis and demonstrate the potential utility of using neural decoding to explore the nature of lexical representation.

Topic Areas: Speech Perception; Computational Approaches

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Kinesthetic working memory is used to align gestures with speech and visuospatial working memory is recruited to understand gestures

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Prior work suggests both visuospatial and kinesthetic working memory (WM) capacity are related to behavioral measures of sensitivity to co-speech gestures. Here we examine how individual differences in each WM capacity relate to neural indices of real-time speech and gesture processing. Visuospatial WM was assessed in 25 healthy adults via a computerized version of the Corsi block task, while kinesthetic WM was assessed via the movement span task that tracks the ability to accurately reproduce short sequences of meaningless movements of the hands and arms. Following WM assessment, EEG was recorded as participants viewed a series of discourse videos with either congruent or incongruent pairings of speech and gesture. Following each discourse clip, picture probes related to speech were presented to assess how multimodal discourse primed the visual system for subsequent input. A nonparametric cluster-based permutation analysis of event related spectral perturbation (ERSP) data induced by the discourse videos revealed greater alpha band (8-10Hz) suppression during incongruent than congruent speech-gesture pairings ($p<0.05$). A separate analysis revealed changes in low beta band activity (14-16Hz) in response to speech gesture congruity were related to individual differences in kinesthetic WM ability, an effect focused over left temporo-parietal sites and beginning approximately 100ms after video onset. Individual differences in visuospatial WM ability were not related to gesture congruity effects in ERSP to the videos, but post hoc analysis indicated a relationship between visuospatial WM scores and alpha suppression levels during all discourse videos ($p<0.01$), suggesting greater engagement with videos in participants with superior visuospatial abilities. Visuospatial WM scores were also associated with gesture congruity effects on the N300 and N400 components of the event-related potentials (ERPs) elicited by picture probes ($p<0.025$). After the EEG experiment, participants were again shown discourse videos and asked to make explicit judgments about the relationship between the speech and the gesture. Performance on this offline gesture congruity task (d') was positively associated with kinesthetic WM scores, replicating previous work and providing evidence that kinesthetic WM helps promote sensitivity to speech-gesture congruity ($b=0.40$, $t=2.94$, $p<0.01$). Offline sensitivity to the relationship between speech and gestures may be related to the beta-suppression effect observed during real time viewing of multimodal discourse. The timing of that effect (beginning ~100ms after video onset) and the hypothesized role for beta band activity in the synchronization of neural events suggests kinesthetic WM helps to coordinate the perception of prosodic fluctuations in speech with movements of the speaker's body. The relationship between visuospatial WM and gesture congruency effects on picture probes suggests visuospatial resources related to the generation and maintenance of imagery mediate sensitivity to the meaning of co-speech gestures.

Topic Areas: Meaning: Discourse and Pragmatics; Perception: Speech Perception and Audiovisual Integration

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Flexible recruitment of sensorimotor information during language processing: An EEG Study

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Grounded theories of semantic representation propose that simulations of sensorimotor experience are activated when processing the meaning of a word. These theories are supported by behavioural evidence that words high in body-object interaction ratings (BOI; the ease with which the human body can interact with a word's referent) are processed more quickly than those low in BOI ratings, the BOI effect. Further evidence suggests that this sensorimotor information may be flexibly recruited based on task demands. Tousignant and Pexman (2012) found that the BOI effect in behavioural responses was only present when participants were asked to decide if a word was an entity but not when asked to decide if a word was an action. In the present study we replicated Tousignant and Pexman (2012) with the addition of EEG recording, to further understand the impact of task demands on the BOI effect. We hypothesized that differences in event-related potentials (ERPs) linked to semantic processing (the N400 and P600) would reflect the influence of top-down task demands on bottom-up semantic activation processes. We recruited 90 participants (40 in Experiment 1, 50 in Experiment 2) who completed a semantic decision task during EEG recording. Participants were randomly assigned to one of two task conditions ("Is the word an entity?" or "Is the word an action?"). The same stimuli were used for both conditions; 100 entity words (50 high BOI entity and 50 low BOI) and 100 action words. We used a data-driven multivariate analysis technique to investigate differences in ERP activity while processing action words, high BOI entity words, and low BOI entity words in both task conditions. Our behavioural results replicated those reported in Tousignant and Pexman (2012), wherein a BOI effect was only observed in the entity task condition. Preliminary results from the ERP analysis identified significant latent variables in both experiments that differentiated between neural activity related to action word processing compared to high and low BOI entity words in the action task condition and compared to action words in the entity task condition. These differences were observed as sustained positivity for action words in the action task condition at frontocentral electrodes between 400 - 800ms post stimulus onset. This same difference was observed as a sustained negativity for action words in the action task condition at bilateral temporal and parietal electrodes between 400 - 800ms post stimulus onset. Finally, we observed a more negative-going waveform for action words in the action task condition at occipital electrodes 400 - 600ms post stimulus onset. Our preliminary results suggest that differences in task demands are evident in associated neural activity, however these differences do not mirror those observed in the behavioural data. Action-related words were related to differences in amplitude in the N400 time window relative to high and low BOI words in the action task condition and compared to action words in the entity task condition, suggesting that action-specific information was recruited preferentially in the action task condition.

Topic Areas: Meaning: Lexical Semantics; Multisensory or Sensorimotor Integration

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Differential selectivity of the left and right hemisphere language regions for non-linguistic processing

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The language network, which supports comprehension and production beyond perceptual input and output motor processes, is lateralized to the left hemisphere (LH) in most individuals. However, highly reliable—albeit lower in magnitude—responses to language are also observed in the homotopic right hemisphere (RH) areas (e.g., Mahowald & Fedorenko, 2016). The relative contributions of the LH and RH language network to language and other cognitive functions remain debated. The degree of a brain region/network's functional specialization can critically inform its functions (e.g., Kanwisher, 2010). Chai et al. (2015) used dynamic network modeling to show that the RH language regions constitute the flexible 'periphery' of the language network: they co-activate with different regions at different times. In contrast, the LH language regions consistently co-activate with one another and thus constitute a stable 'core'. Given the hypothesis advanced by Bassett et al. (2013)—whereby the inter-regional coupling flexibility of a given brain region over time is inversely related to its degree of functional specialization—RH language regions should be less functionally specialized for language compared to the LH language regions. Yet, studies that probed a relatively restricted range of non-linguistic functions did not observe reduced specialization for language in the RH language regions (e.g., Fedorenko et al., 2011; Deen et al., 2015). Here, we comprehensively evaluate the degree of functional specialization in the LH and RH language regions using data from 34 experiments (68 conditions) across a total of 761 participants. Each participant performed a language localizer task, which robustly identifies language-responsive cortex (Fedorenko et al., 2010; Braga et al., 2020), and different subsets performed diverse non-linguistic tasks (n across experiments ranged from 11 to 715; average: 44.7±20.4, median: 18). The non-linguistic tasks spanned a broad range of perceptual, cognitive, and motor functions, including visual and auditory processing of both social and non-social stimuli, hand and face motor control, music perception, numerical cognition, executive function tasks, categorization, visual event semantics, and computer code comprehension. Averaging across the different non-linguistic conditions, we observed stronger responses in the RH language regions compared to the LH language regions, as predicted by Bassett et al. (2013). Furthermore, we observed a high correlation across the non-linguistic conditions in how strong of a response they elicited in the LH vs. the RH ($r=0.63$; $p<0.001$): if a condition elicited a low response in the LH, it also tended to elicit a low response in the RH. However, a finer-grained examination of the different conditions revealed interesting differences across domains. In particular, whereas social stimuli (e.g., faces and bodies), music conditions, and visual meaningful events elicited stronger responses in the RH language regions, categorization and computer code comprehension elicited stronger responses in the LH language regions. Tasks taxing numerical cognition and executive functions elicited similarly low responses in the LH and RH language regions. Thus, reduced selectivity in the RH language regions is not ubiquitous. Understanding why certain non-linguistic functions elicit stronger responses in the RH language network may inform the nature of its contributions to language and cognition more generally.

Topic Areas: Control, Selection, and Executive Processes; Meaning: Combinatorial Semantics

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Music-related neural and environmental predictors of early language development

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An increasing number of studies show that rhythm and language skills are associated and that rhythm and language are heritable. Motivated by these and converging results, we proposed the Atypical Rhythm Risk Hypothesis which posits that individuals with poor rhythm are at higher risk for developmental speech/language disorders (Ladányi et al., 2020, Wiley Cog. Sci.). The current project aims to investigate the longitudinal relationship between rhythm and language development, specifically testing the Atypical Rhythm Risk Hypothesis by investigating if rhythm skills of infants or their parents could predict children's risk for speech/language disorders. In our ongoing longitudinal study, first, we measured infants' and their parents' beat processing when the infant was between 6 and 12 months with a passive listening EEG paradigm (adapted from Iversen et al., 2009, ANYAS). Participants were presented with a repeated tone-tone-rest pattern in 20 blocks in which the position and the marking of the beat was manipulated. In half of the blocks (physical accent condition) the strong beat was marked with increased intensity while in the other half of the blocks (inferred beat condition) a physical accent was present at the beginning of the block but it was then phased out in order to create the illusion of the beat without the physical accents. Parents also completed a behavioral rhythm discrimination task and parent musicality, home musical environment and demographic questionnaires. When children turn 4, they will return for a speech-language evaluation. Between the two time-points, children's vocabulary development is measured with parent questionnaires at 12, 18, 24 and 36 months. In the talk, we will discuss preliminary data from the study (n = 45 infant-parent dyads with data up to the 24 months vocabulary assessment). Results from a cluster-based permutation tests of event-related potentials (ERPs) and evoked time-frequency activity in the beat processing task show that both parents and infants discriminated between beat patterns, both when the beat was physically accented and when the beat was inferred. Infants with a larger ERP response to the beat at the onset of inferred beats have a larger receptive vocabulary reported by the parent at 12 months ($r = .53$, $p = .014$). In addition, home musical environment shows a positive relationship with expressive vocabulary at 18 ($r = .38$, $p = .012$) and 24 months ($r = .41$, $p = .013$). These associations remain significant when socio-economic status is taken into account. Our results suggest that the EEG beat processing task is a feasible measure of rhythm skills at infancy. The association of beat processing with 12-month vocabulary size is consistent with the hypothesis that domain-general beat processing abilities support or share biological processes with early word-learning, potentially by facilitating word segmentation. The longitudinal relationship between home musical environment at infancy and vocabulary development in the second year of life suggests that a more enriched musical environment could support language acquisition. These results converge with a growing body of work showing overlaps between musical development and language development.

Topic Areas: Development; Perception: Auditory

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Neural tracking of speech and song in children with and without dyslexia

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A growing literature has examined neural phase-locking to speech rhythms in dyslexia, and suggests marked deficits in processing the slow syllable rhythms of speech. This rhythmic processing deficit in children with dyslexia is consistent with the view that reading difficulties are related to more basic problems in phonological processing. Of interest in the current study is whether these deficits also extend to other domains relying heavily on temporal processing, such as music. To address this, we examined how children with and without dyslexia neurally track the rhythms of natural spoken and sung utterances using EEG. Children completed reading, phonological processing, and musical beat processing tasks to understand the relationship between the neural processing of speech rhythms, musical rhythms, reading, and phonological awareness. We used the neural measure of cerebro-acoustic phase coherence (henceforth, neural tracking), which estimates how consistently individual's neural activity aligns with the amplitude envelope of the spoken and sung stimuli. Forty-five 8- to 10-year-old children (18 poor readers) showed significant neural tracking of low-frequency (delta/theta) syllable information for both speech and song, but there was no difference between neural tracking for spoken and sung utterances. Poor readers showed significantly greater neural tracking than typically developing readers in a higher frequency band (beta: 12-20 Hz) corresponding to the phoneme rate in our stimuli. This increased neural tracking correlated significantly with the word reading efficiency scores (TOWRE) suggesting a relationship between abnormal neural processing and reading deficits across good and poor readers. There were no differences between the poor and typically developing readers when tracking the rhythms of song, suggesting that the musical structure of song may allow children with dyslexia to process speech in the same way as their typically developing peers. Further connections between musical beat processing, neural processing, and reading ability will be discussed.

Topic Areas: Disorders: Developmental; Prosody

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The amplitude modulation of sounds is crucial for categorizing speech and music

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Despite our increasingly rich understanding of how humans process speech and music, surprisingly little is known about how they are treated as different auditory signals in the first place. From the perspective of acoustics, the properties of the signals can be differentiated. It has been shown that speech and music tend to have different amplitude modulation (AM) rates. Specifically, the AM rate of speech peaks between 4 and 5 Hz, while the AM rate of music tends to be slower, emphasizing modulation rate around 2 Hz (Ding et al., 2017). In addition, it is often argued that the AM of music tends to be more temporally regular or isochronous than speech (Kotz et al., 2018). Based on these insights, we hypothesized that the AM temporal features of an acoustic signal, especially its peak rate and regularity, are critical factors that determine whether a signal will be categorized as speech or music. Here we parametrically manipulated (i) the AM peak frequency (0.6 – 6.0 Hz) and (ii) the AM regularity to generate a variety of signals with varying AM envelopes. The AM envelopes were synthesized with an identical broadband low-noise noise carrier sound. Each stimulus is an amplitude modulated noise excerpt with manipulated AM features. More than 300 participants have taken part in two online behavioral experiments. On each trial, they listened to one of the generated stimuli and were prompted to make a binary judgment on whether it sounds more like a “speech” or a “music” recording. The preliminary results support the hypothesis that, across participants, the sound excerpts with slower peak AM rate and more temporally regular AM were more likely to be judged as music. These factors appear to have around 36-50% of explanatory power, suggesting that the amplitude envelope alone is essential to differentiate speech and music. Furthermore, the stronger the music-speech/slow-fast AM association is correlated with higher musical sophistication of the participants. To the best of our knowledge, this is the first study showing that the AM temporal features are critical low-level factors of determining a sound to be interpreted as speech or music.

Topic Areas: Perception: Auditory; Speech Perception

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A systematic review and meta-analysis of speech-in-noise perception in musicians

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Introduction. The ability to process speech in noise (SPiN) is essential for everyday communication. The literature shows that SPiN is particularly challenging in energetic maskers, speech maskers with various talkers, especially with 2-3 talkers, and when the signal-to-noise ratio (SNR) is negative. Furthermore, a negative effect of ageing on SPiN performance, particularly in speech maskers, is well documented. Indeed, SPiN perception declines with age, which negatively impacts communication-mediated activities, including social participation. It is therefore crucial to find strategies to mitigate this decline. Because it involves cognitive and auditory training and is associated with brain plasticity across multiple functional systems, musicianship has raised interest as a potential prevention/rehabilitation tool for SPiN performance decline. Yet, the literature on the potential benefits of musicianship on SPiN performance is mitigated, with some studies showing a musician advantage and others not. We therefore conducted a systematic review of the literature and performed the first meta-analyses of the effect of musicianship on SPiN performance, including an evaluation of the effect of age. We hypothesized that musicians would outperform non-musicians in conditions known to be challenging (energetic maskers, speech maskers with various talkers, negative SNR). We also expected to observe a greater advantage in older than in younger musicians, especially in speech maskers. Method. 49 articles comparing the performance of musicians and non-musicians in ≥1 SPiN behavioural task were selected after a literature search on PubMed and PsycNet. Study quality was assessed using the QualSyst tool (Kmet et al., 2004). The participants' demographic information, their musical experience and the characteristics of the SPiN tasks were extracted. Eight separate random-effect meta-analyses were performed for the following SPiN conditions: speech in energetic maskers, speech in speech maskers (1-talker, 2-talker and 4-talker masker), speech in spatially separated masker and different SNR levels (< 0 dB, 0 dB > 0 dB). The participants' mean age was used as a continuous moderator. Results. Significant effect sizes in favour of musicians were found for speech in energetic maskers, speech in 2- and 4-talkers and for stimuli at SNR < 0 db and 0 dB. No significant effects were found with 1-talker maskers, spatially separated maskers and SNRs > 0 dB. A significant positive effect of age was found in the energetic and SNR = 0 dB analyses but could not be robustly and consistently assessed due to the paucity of studies on adults aged > 55 years (n=3). Conclusion. This is the first systematic review and meta-analysis on the effect of musicianship on SPiN performance. Our results based on the existing literature are compelling - musicianship appears to have a significant effect in contexts producing significant masking in non-musicians. This pattern of results supports an advantage for musicians on SPiN performance. Further studies, especially on older participants, are needed to confirm and extend the present conclusions on the effectiveness of training methods based on musical skills for SPiN perception.

Topic Areas: Speech Perception; Perception: Auditory

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Neural responses while listening to rhythmically varied stories

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Despite its many functions in service of communication efficacy, prosody is one of the most overlooked features of language. Prosodic cues such as speech rhythms (i.e., patterns of stressed and unstressed syllables) are also known to facilitate speech perception. Speech rhythms are represented in the speech envelope. The phase of cortical activity follows that of speech envelope, a phenomenon known as envelope tracking. Two complementary measures of neural phase locking characterize envelope tracking. (1) Cerebro-acoustic coherence (CAC) in theta-delta bands (1-10 Hz) provides a measure of neural responses across the time course of continuous speech; (2) Inter-event phase coherence (IEPC) is a measure of neural phase-locking time-locked to specific acoustic events in the speech signal. We have previously shown that IEPC over speech-related cortical areas increases following times of rapid increases in the speech envelope (peakRate events), which mark stressed vowel onsets. Here we examined whether neural engagement while listening to continuous speech differs based on its rhythmic structure. To this end, we examined three electrophysiological measures: CAC, as well as broadband evoked response potentials (ERPs), and IEPC time-locked to peakRate events. We compared these measures in response to metrically regular and non-regular stories. We also examined whether the magnitude of neural responses to acoustic edges can be predicted based on individual differences in participants' musical rhythm perception skills. 26 neurologically healthy, native speakers of English (21 F) aged 18-22 yrs (M=18.8) participated. High-density EEG was recorded while participants listened to two 6-minute-long audio recordings of children's stories, one with notably regular metrical structure, and the other with non-regular metrical structure. Participants also performed a musical rhythm discrimination test, which comprised of simple (strongly beat-based) and complex (syncopated) rhythm conditions. As predicted, we found evoked responses and increased IEPC in the theta-delta bands to acoustic edges in both conditions, consistent with previous results. Crucially, IEPC was higher for metrically regular sentences in low theta (~3 Hz), and for metrically irregular sentences in the delta range (~1 Hz). As with IEPC, higher CAC was found for metrically regular vs irregular sentences in the theta range (~4-5 Hz). At ~1 Hz, CAC was higher for metrically irregular vs metrically regular sentences. In addition, ERPs showed frontocentral negativity at 300-400ms to more metrically irregular speech, consistent with previous findings. Individual differences in complex musical rhythm sensitivity (measured behaviorally) were positively correlated with theta IEPC to metrically regular sentences, which are thought to mark syllabic stress. In summary, our results suggest neural engagement with metrically predictable syllable patterns such as in rhythmically regular speech. Neural engagement with temporal patterns is at slower time scales in non-regular speech. Further, results suggest that individual differences in sensitivity to a musical rhythm may modulate neural engagement with metrical patterns in speech. These results extend previous findings of the role of peakRate cues in the processing of acoustic edges by showing their importance at the level of metrical patterns in sentences and also align with literature linking individual differences in musical rhythm ability with speech rhythm processing.

Topic Areas: Perception: Speech Perception and Audiovisual Integration; Speech Perception

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Neural decoding reveals representations of perceptual category and perceptual ambiguity during speech perception

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Robust and efficient speech perception relies on interpreting acoustically-variable phoneme realizations, yet prior neuroimaging studies are inconclusive regarding the degree to which acoustic-phonetic detail persists over time as categorical representations arise. We hypothesized that this might depend on task demands, such that overt categorization, in comparison to passive listening, would attenuate the representation of within-category detail over time. We addressed this question by using time-resolved neural decoding to quantify the (dis)similarity of brain response patterns evoked by the same stimuli presented during two different tasks (Beach et al., 2021, Neurobiology of Language). We recorded magnetoencephalography (MEG) from 24 adults during exposure to 40 tokens each of 10 steps of an acoustic continuum ranging from /ba/ to /da/, presented in pseudorandom order. In the passive task, participants performed visual target detection to maintain arousal but were told they could ignore the sounds. In the active task, participants labeled each stimulus as either "ba" or "da" via counterbalanced and delayed button-press. We performed cross-validated classification of the MEG data using linear support vector machines. Classifiers were trained to distinguish the perceptual label as applied by the participant (binary) as well as stimulus identity (pairwise). Perception of "ba" vs. "da" was successfully decoded from the MEG data. Left-hemisphere data were sufficient for decoding the percept early in the trial, while right-hemisphere data were necessary but not sufficient for decoding at later time points. Stimulus representations were maintained longer in the active task than in the passive task, perhaps due to decision-related processing. However, contrary to predictions, we did not observe a loss of within-category detail when an overt categorical response was required. Instead, in both tasks, a representation of perceptual ambiguity (that distinguished endpoint from middle tokens) dominated the second half of the trial. These results suggest that the speech-sound categorization process does not require the loss of within-category detail. Results are discussed in the context of theories of perceptual decision-making and in relation to models of speech perception and spoken-word recognition that highlight the utility of within-category detail.

Topic Areas: Speech Perception; Computational Approaches

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Predicting words and syllables: neural oscillations to “koguka” in adults and children

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Perception of speech makes use of inferences shaped by experience with the native-language phonology. These inferences are developed early in life via experience with input. The current study examines this process using neural oscillations to syllables sequences to elucidate the development of these prediction skills. The electroencephalogram (EEG) was recorded to sequences of 10 3-syllable words, where the second and third syllable were exchanged in two of the 10 words (koguka -koguka -koguka- kokagu, koguka, etc.). The words (.55 s duration) occurred at a rate of .95 s within the sequence of 10, with an inter-sequence interval of 1.9 s. Fifty percent of the sequences had the stimulus change (deviant) in the 4th and 8th positions, 25% had the deviants in the 5th and 10th and 25% had deviants in the 6th and 10th positions. The EEG was recorded from 12 adults and eight one- to four-year old children for a total of 400 sequences from 65 scalp sites using a geodesic net. The trains were segmented into 12.56 seconds, beginning 2 sec before the 1st stimulus of the sequence. Results focus on the sequences with the change in the 4th and 8th because we had sufficient trials from the children. Analyses on Fz (average-referenced) revealed peaks of power at 1.035 Hz (.966 period) for adults and 1.11 Hz (.897 period) for the children, roughly corresponding to the word rate of speech. The adult and children also showed a clear peak at 2.07 Hz (.483 s period). Only the adults showed a clear peak at 5.25 Hz (.19 s period), with children showing multiple peaks between 6 and 8 Hz. The Continuous Wavelet Transform (CWT – using Morlet wavelet) on the single trials revealed increased power between 2 and 5 Hz at the onset of the sequence of 10 stimuli for adults, but not for children. Adults, but not children showed increased power in the 1-Hz range after the 5th stimulus, perhaps related to predicting the .95 s rate of words; adults also showed suppression of 2-Hz power following the onset to the deviant (kokagu) word, but this suppression occurred closer in time to the onset when in the 8th compared to 4th word position. Children showed increased power between 2 and 5 Hz at the onset of the deviant in 8th position. These findings suggest that adults were tracking and predicting timing of sequence onsets, word rate, word duration, syllable duration, and the deviant in the 8th position. Children showed evidence of predicting word rate, word duration and the deviant in the 8th position. The different pattern to the deviant, specifically, power suppression for adults and increased power for children may reflect different types of mismatches responses, with adults showing a negative mismatch response and very young children showing a positive mismatch response. These findings are consistent with other studies indicating that young children compute statistical probabilities for speech, but also provide insight on the brain correlates associated with this process.

Topic Areas: Speech Perception; Development

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Audiovisual speech perception in typically hearing and cochlear implant-using children: an ERP study

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Most spoken language occurs under conditions in which the listener has access to both auditory (i.e. acoustic) and visual (i.e. facial) information. A large body of behavioral research shows benefits of audiovisual (A/V) over audio-only (A) presentations in word recognition, lexical decision and sentence processing and under conditions of noise (Bernstein et al., 2004; Ma et al., 2009). Current electrophysiological studies of A/V speech perception have shown the effects of the modality of presentation on early ERP components (N1/P2) and later N400 components (Basirat et al., 2018; Brunellière et al., 2020; Pilling, 2009). These components are consistently responsive to speech, with amplitudes and latencies that are modulated by the presence of visual information. Data indicate that there is typically an attenuation of the ERP components associated with speech processing under conditions of A/V versus A-only presentations. Developmental changes have also been reported, with younger children showing less influence of visual speech cues on auditory ERP components compared to older children (Knowland et al., 2014). We investigate the contributions of A/V speech processing in congenitally deaf children who have received a cochlear implant (CI). Continuous EEG data was collected from deaf children with CI ($n = 30$; mean age = 81 mos) and typical hearing children ($n = 19$; mean age = 75 mos) during a word-picture priming paradigm. This paradigm consisted of Audio-Visual presented word primes that preceded picture targets. In the current work we explore the effects of processing of the spoken Audio-Visual primes in these data. Results demonstrate more positive P1 and P2 responses for CI-using children compared to typical hearing controls ($p = .017$ and $p = .043$, respectively), but no group differences in N400 responses ($p = .142$). We also explored age- and experience-related factors. Overall visual P1 amplitude was correlated with participant age ($R = 0.286$, $p = .004$). P2 latency was found to decrease with age in the control group ($R = -0.199$, $p = .014$), but not in the CI group ($R = -0.07$, $p = .278$). However, CI users' time-in-sound was positively correlated with P2 amplitude ($R = 0.18$, $p = .005$). These P2 data may suggest differences in attentional mechanisms related to A/V speech in experienced CI users. In sum, audiovisual speech may evoke greater visual reactivity and differentially engage attention in CI users relative to controls. These differences in early sensory and attentional processing, however, lead to comparable comprehension and semantic processing between groups as evidenced by similar N400 responses. These data help to inform our understanding of attentional and perceptual speech processing in children with cochlear implants.

Topic Areas: Development; Perception: Speech Perception and Audiovisual Integration

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Right posterior temporal cortex supports integration of phonetic and talker information

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Bayesian models of spoken word recognition posit that in order to accurately perceive the speech signal, listeners can condition phonetic identity on talker information (Kleinschmidt, 2019). Consistent with this, perceptual learning studies indicate that listeners can adapt to the idiosyncratic ways that different talkers produce their speech sounds, maintaining distinct sets of beliefs for distinct talkers (Kraljic & Samuel, 2007). Neuroimaging data suggest that talker-specific phonetic learning is partly supported by the right posterior temporal cortex (Myers & Mesite, 2014; Luthra, Correia, Kleinschmidt, Mesite, & Myers, 2020). This is a striking suggestion; though the right hemisphere has been implicated in talker processing (Van Lancker & Kreiman, 1987), it is thought to play a minimal role in phonetic processing, at least in comparison to the left hemisphere (Hickok & Poeppel, 2007). In the current work, we test the hypothesis that the right posterior temporal cortex supports talker-specific phonetic learning through the integration of phonetic information and talker information. Listeners (N=20) completed a lexically guided perceptual learning task during which they heard a male talker and a female talker. One talker produced an ambiguous /s/-/ʃ/ blend in lieu of /s/ and one produced the ambiguous fricative in place of /ʃ/. Functional activation was measured using fMRI and submitted to multi-voxel pattern analyses. Of interest was whether voxels in the right temporal cortex could be used to classify trials both on the basis of talker identity and on the basis of phonetic identity. We did not observe perceptual learning in our data, and follow-up experiments suggest this was attributable to our in-scanner headphones, which attenuated frequencies above 5000 Hz. Nevertheless, searchlight analyses indicated that the patterns of activation in the right superior temporal sulcus (STS) contained information both about who was talking and what phoneme they produced. We take this finding as evidence that talker information and phonetic information are integrated in the right STS. We also examined how the right-hemisphere voxels that contained information about talker identity — namely, the right superior temporal gyrus (STG) and right STS — were functionally connected to other parts of the brain. We found that when listeners were engaged in phonetic processing, there was increased connectivity between the right STG/STS seed, left hemisphere regions associated with speech perception, and right hemisphere regions associated with talker processing. Thus, our functional connectivity analysis suggests that the process of conditioning phonetic identity on talker information involves the coordinated activity of both the left and right hemispheres. Overall, this work supports a role for the right hemisphere in talker-specific phonetic processing. Our results suggest that the integration of phonetic information and talker information is achieved through two mechanisms: (1) the simultaneous encoding of phonetic information and talker information in the right STS and (2) the coordinated activity of a left-lateralized neural system for phonetic processing and a right-lateralized talker processing system. Future work will be needed to investigate whether the right STS plays a similar role in perceptual learning specifically, since we did not observe learning in the current study.

Topic Areas: Speech Perception; Perception: Auditory

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Using TMS to evaluate a causal role for right posterior temporal cortex in talker-specific phonetic processing

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Individual talkers differ substantially in how they produce speech sounds. For instance, talkers vary in the specific voice-onset time (VOT) they produce for voiceless stop consonants (/p/, /t/, /k/ in English; Allen, Miller, & DeSteno, 2003) and these differences are stable across linguistic contexts (Theodore, Miller, & DeSteno, 2009). Listeners are sensitive to such differences and can explicitly indicate what variation is typical of a talker (e.g., Allen & Miller, 2004). Theories suggest that maintenance of talker-specific phonetic details benefits speech perception, with perception guided by listeners' knowledge of whether a given talker is likely to produce a specific phonetic variant. In a previous fMRI study, Myers and Theodore (2017) exposed listeners to two talkers: one who produced /k/ with short VOTs and one with relatively longer VOTs. Through exposure, listeners learned which variant was typical of each talker. In a subsequent in-scanner phonetic categorization task, listeners heard typical and atypical variants from each talker. A cluster in the right middle temporal gyrus (RMTG) was sensitive to how typical the variant was for each talker, consistent with a burgeoning literature suggesting that the right hemisphere may play a key role in conditioning phonetic identity on talker information (Luthra, 2021). The current work used transcranial magnetic stimulation (TMS) to test whether the RMTG plays a causal role in processing talker-specific phonetic variation (N=27). In each of three experimental blocks, listeners heard two talkers: one who produced a voiceless stop with short VOTs and one with relatively longer VOTs. During training, listeners made a four-alternative forced-choice to indicate both who was talking (e.g., Peter or Sheila) and what word they said (e.g., gain or cane). Prior to each training trial, listeners received TMS. A different stimulation site was used for each block, with sites at the RMTG, left MTG, and scalp vertex (control). At test, listeners heard speech from one of the two trained talkers and indicated which of two variants (short-VOT or long-VOT) was typical for that talker. During training, listener accuracy was at ceiling for talker identification, regardless of stimulation site. Though listeners were also near ceiling in their phonetic decisions, logistic regression analyses indicated a trend towards an effect of stimulation ($p = 0.06$). Specifically, listeners were less accurate in deciding which word they heard (e.g., gain or cane) after RMTG stimulation (96.3 ± 18.9; mean ± SD) compared to LMTG (98.8 ± 11.0) and control (97.9 ± 14.4) stimulation. However, stimulation did not influence test performance; regardless of stimulation site, listeners learned which phonetic variant was typical of each talker. The relatively modest effects observed here are consistent with the view that talker-specific phonetic processing is supported by the posterior temporal cortex bilaterally. When the RMTG was stimulated, listeners may have been able to rely on the left hemisphere to compensate (and vice versa). Thus, even though the RMTG is functionally recruited when listeners condition phonetic identity on talker information, impairing its function may only have modest consequences for talker-specific phonetic processing.

Topic Areas: Speech Perception; Perception: Auditory

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A computational investigation of the transformation from talker-specific detail to talker-invariant lexical representations

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Listeners accommodate a tremendous amount of talker variability during spoken word recognition, readily recognizing speech produced by myriad talkers despite significant differences in acoustic-phonetic patterns (Joos, 1948). However, a key barrier to explaining listeners' robust performance across talkers is the fact that most computational models of spoken word recognition represent speech inputs in terms of abstract phonetic features, thereby sidestepping the issue of talker variability. Recently, our team introduced EARSHOT, a neural network model of human speech recognition that works on real speech as it unfolds over time (Magnuson et al., 2020). EARSHOT maps spectrogram-based input patterns to a lexical-semantic output layer via a hidden layer of long short-term memory (LSTM) nodes. We observed human-like patterns of lexical competition and moderate generalization to untrained words and talkers. Furthermore, despite not being trained explicitly on phonetic targets, EARSHOT's hidden units exhibited phonetically organized responses resembling those observed in human superior temporal gyrus. In this follow-up work, we conducted a series of Representational Similarity Analyses (RSAs; Kriegeskorte et al., 2008) to characterize how talker and lexical information are represented in EARSHOT. We first constructed Representational Dissimilarity Matrices (RDMs) to describe the similarity structure in the activation patterns of 1161 different words each spoken by 16 different talkers. We constructed separate RDMs for the input layer and the hidden layer. We compared these to two theoretical RDMs: one where the hypothesized similarity structure was defined by word identity (regardless of talker) and one where the similarity structure was defined by talker identity (regardless of the word). The EARSHOT RDMs were compared to the theoretical RDMs, with one set of analyses collapsing across time (i.e., concatenating the patterns from all time steps) and another considering the pattern of activation at each time step separately. We found that word identity was not strongly represented in the input state patterns ($r = 0.014$, $p < 0.01$, collapsed across time), reflecting the known lack of invariance between acoustic signal and linguistic units (Liberman et al., 1957). However, talker information was strongly represented in the input patterns ($r = 0.251$, $p < 0.01$, collapsed across time). Over-time analyses revealed that the strength of this latter correlation varied as the input unfolded; fluctuations in this correlation appear to be associated with coarse-grained talker-specific details, such as characteristic speaking rate. In the hidden layer, we observed a relative increase in the extent to which word identity was represented ($r = 0.104$, $p < 0.01$, collapsed across time) and a relative decrease in the extent to which talker information was represented ($r = 0.094$, $p < 0.01$, collapsed across time). Over-time analyses indicated that the strength of the former correlation increased as the input unfolded, while the strength of the latter correlation decreased at later time steps. Thus, the hidden states appear to reflect an intermediate stage in the transformation from talker-specific surface details of utterances to abstract, talker-invariant lexical representations. Beyond elucidating how EARSHOT works, these analyses may generate new neural hypotheses about similar transformations in the brain.

Topic Areas: Computational Approaches; Speech Perception

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Seeing the Face of the Talker Normalizes BOLD Pattern Responses to Noisy Speech

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Viewing the talker's face improves comprehension of noisy auditory speech. To investigate the neural computations underlying this perceptual benefit, we measured BOLD fMRI pattern responses in the posterior superior temporal gyrus and sulcus (pSTG/S) of 14 healthy participants. Participants were presented with 2-second audiovisual recordings of single words (297 words from 12 different talkers) in five different formats: clear audiovisual (AcV); noisy audiovisual (AnV); clear auditory-only (Ac); noisy auditory-only (An); and visual-only (V). BOLD fMRI data was collected using a Siemens Prisma 3 tesla scanner, with words presented in a silent interval inserted between acquisitions of the multiband pulse sequence. Following presentation of each word, participants reported whether the word was intelligible ("Y") or not ("N") with a button press. Seeing the face of the talker produced a seven-fold increase in the likelihood of a "Y" rating (odds-ratio = 7.0, p = 10-8; 38% intelligible for An vs. 71% for AnV). Noisy word trials were post hoc sorted into "Y" trials (An-Y, AnV-Y) and "N" trials (An-N, AnV-N), allowing for a comparison between trials that were physically similar but perceptually different. Voxel time series were analyzed using a generalized linear model with seven regressors of interest (AcV, AnV-Y, AnV-N, Ac, An-Y, An-N, V) using the AFNI program 3dDeconvolve. The mean percent signal change across conditions was calculated for each voxel and subtracted from the response to each individual condition in order to increase the dynamic range of the fMRI pattern correlation. To compute the fMRI pattern similarity between two conditions, the normalized percent signal change in each pSTG/S voxel for the first condition was correlated with the normalized percent signal change in the second condition, resulting in a single correlation value for each pair of conditions for each of the 28 hemispheres. Interestingly, the response pattern evoked by intelligible noisy audiovisual speech was very similar to the response pattern evoked by clear audiovisual speech, even though they were physically very different, r(AcV, AnV-Y) = 0.65 +- 0.48 (mean +- SEM). In contrast, the response patterns evoked by intelligible and unintelligible noisy audiovisual speech were very different, even though the stimuli were physically similar, (AcV, AnV-N) r = 0.10 +- 0.13. Intelligibility had a weaker effect on the response patterns for auditory-only speech, r(Ac, An-Y) = 0.44 +- 0.09 vs. r(Ac, An-N) = 0.31 +- 0.10, as confirmed by a significant interaction between intelligibility and stimulus format in a linear mixed effects model. This demonstrates that intelligibility and the presence of visual speech are both important drivers of response patterns in pSTG/S. When noisy audiovisual words are intelligible, the pattern of brain response in pSTG/S is similar to that observed during clear audiovisual speech, suggesting the normalization of response patterns as a neural mechanism for the perceptual benefit of seeing the face of the talker.

Topic Areas: Perception: Speech Perception and Audiovisual Integration; Multisensory or Sensorimotor Integration

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Acoustic and language-specific processing of phonological sequence onsets in the low gamma- and theta frequency bands

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Temporal processing models suggest that the rate of acoustic change of syllabic level- and phonemic level-structures give rise to entrainment in the theta- and low gamma (LG) frequency bands, respectively. It has been suggested that this hierarchical-coordinated decoding of speech facilitates speech perception. However, few studies have investigated whether language exposure to phonotactic patterns modulates sensory processing in the theta- and LG bands. To elucidate processes that facilitate speech perception, time-frequency (T-F) analyses of EEGs obtained from 24 native speakers of English and 24 native speakers of Polish (late language learners of English) were conducted. Participants listened to same and different nonword pairs within counterbalanced attend- and passive-listening conditions, with each testing condition separated by a minimum of two months. Nonwords within the pairs contained the phonological sequence onsets /pt/, /pət/, /st/, and /sət/ that occur in both the Polish and English languages with the exception of /pt/, which never occurs in English without a preceding vowel. A source localization model to the first word in the pairs was created from auditory-evoked potentials (AEP) that transformed the 64-channel EEG into brain source-level channels for T-F analyses (BESA Research 7.1). The model was created from ~53,000 single AEP trials filtered between 1-55 Hz with 1500 ms epochs (-500 pre- 1000 post-onset). Goodness of fit for the model for each onset, language group and condition was greater than 98%. T-F measures of spectral power and inter-trial phase locking (ITPL) in the LG- and theta bands were analyzed from two bilateral, auditory cortical-source channels. Between-language-group analyses to each of the four onsets examined, separately, revealed a single significant language effect. Larger spectral power in LG was found for the English listeners to the unfamiliar /pt/ onsets in the right hemisphere, at early cortical stages during the passive condition. The English group response to the /pt/ onset, which has zero probability of occurrence in the English language, might reflect a right-hemisphere novelty effect. Sensory processing appeared bilateral for the English listeners, whereas the Polish listeners showed a clear left asymmetry to the /pt/ onsets in LG. Onset contrasts that differed by one phoneme (/pt-pət/, /st-sət/, /pt-st/, /pət-sət/) were also examined in each language group, separately. The ITPL pattern to each phonological sequence within the contrast was specific in time and frequency sub-bands within theta. Further, the ITPL patterns were highly replicable across language groups, but appeared modulated by frequency of occurrence of the onset contrast within the language. For example, the pattern of ITPL differences to the /pt-pət/ contrast was similar across language groups, however, differences in ITPL values reached significance only for the Polish group. Thus, phase-locking may be more variable for phonotactic patterns that are absent or rare in one’s language. Language-specific processing in LG and acoustic- and language-specific processing in theta support temporal processing models that view phonemic-level segmentation in LG, along with coordinated activations between theta and LG, to supports speech perception. This study has translational relevance for assessment of individuals with developmental language disorder, dyslexia, and auditory processing disorder.

Topic Areas: Speech Perception; Perception: Auditory

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Extracting phonetic features from natural classes: A mismatch negativity study of Mandarin Chinese retroflex consonants

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The brain codes phonetic features and categories (Mesgarani et al., 2014; Hestvik & Durvasula, 2016; Khalighinejad et al., 2017; Schluter et al., 2017). What is unknown is whether the brain rep-resents phonetic feature classes. Mandarin Chinese is an excellent test case. Mandarin has a rich inventory of retroflex consonants that span multiple manners of articulation: fricatives, affricates, approximants (Lee & Zee, 2003). A powerful tool for understanding how the brain represents speech sounds is the mismatch negativity (MMN; Näätänen, 2001). The MMN is a component in the event-related potential (ERP) that is elicited by a deviant stimulus embedded within a series of repeating standard stimuli. The MMN is typically concentrated over fronto-central electrode sites and peaks between 150–350ms (Näätänen, 2007). In all previous designs, however, any variation present in the standards was intra-category: All standards belong to the same phonetic category (Aulanko et al., 1993; Phillips et al., 2000; Scharinger et al., 2016). To test whether the brain repre-sents feature classes, we introduced inter-category variation in the standards. We observed an MMN only when the retroflex consonants were the standards, suggesting that Mandarin listeners extract the feature [retroflex]. Methods: Twenty-six native speakers of Mandarin Chinese participated in a many-to-one oddball auditory MMN paradigm using electroencephalography (EEG). All syllables were [Cɤː4]. The consonants were either the Mandarin retroflex consonants, i.e., [ʂ tʂ tʂʰ ɻ], or their non-retroflex counterparts, i.e., [s ts tsʰ l]. There were two blocks. Standard retroflex block: standard consonants share feature [retroflex], non-retroflex deviants (underlined), i.e., [… ʂɤ ɻɤ ʈʂɤ ʂɤ tsɤ tʂʰɤ ʂɤ …]. Non-retroflex standard block: non-retroflex standards, retroflex deviants, i.e., [… sɤ tsɤ lɤ tshɤ lɤ ʂɤ tsɤ …]. Participants passively listened to stimuli. We measured the difference in brain responses between the standard and deviant in each block. Permutation tests were used (pFDR < 0.05) to assess statistical differences. Results: We observed an MMN to the non-retroflex deviant embedded in the standard retroflex block. The MMN peaked approximately 300ms post-stimulus onset over fonto-central electrode sites. This suggests that listeners extract [retroflex] despite significant inter-category variation. In the non-retroflex standard block, no MMN was observed. This asymmetric MMN is consistent with previous findings that support underspecified feature representations (Cornell et al. 2013; Eu-litz & Lahiri, 2004; Hestvik & Durvasula, 2016; Scharinger et al. 2016). To determine whether these effects were driven by phonetic properties of the stimuli, we also calculated the identity MMN (iMMN; Pulvermüller & Shtyrov, 2006), which compared the retroflex consonants when they were the standards to when they were deviants. An iMMN to the non-retroflex consonants was observed over centro-parieto-occipital electrode sites instead of fronto-central electrodes. This shift in topography potentially reflects increased difficulty posed by the added variation in the standards. Discussion: Overall, we observed an MMN only when the standards were retroflex: Mandarin listeners grouped the retroflex sounds together and extracted the feature [retroflex]. The brain en-codes abstract phonetic feature classes, despite significant acoustic and phonological inter-category variation, so long as a shared feature binds them together.

Topic Areas: Speech Perception; Phonology and Phonological Working Memory

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“Um…, it’s really difficult to... um… speak fluently”: Neural tracking of real-life spoken language

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Neural speech-tracking experiments usually use idealized speech (e.g., audiobooks) to study how the brain encodes and represents the phoneto-acoustic and linguistic features of speech. However, this type of speech is dramatically different from the type of speech produced spontaneously in real life, which is the type of speech material that our brains deal with daily. Compared to idealized speech, real-life speech contains frequent pauses and fillers (“um”, “er”), it can be highly disfluent and the speech-rate varies over time. Real-life speech is also very associative, as speakers construct their sentences ‘on the fly’, affecting syntactic coherence and leading to highly complex sentences. The current study aims to extend speech-tracking research to authentic real-life spoken language and explore how the brain encodes its unique properties. To this end, we recorded neural activity using EEG from 20 participants as they listened to a recording of a spontaneous, unscripted, personal narrative in Hebrew. Using speech-tracking analysis, we analyzed how brain responses are affected by several inherently variable features in real-life speech. Specifically, using a multiple-regressor approach, we estimated the temporal response function (TRF) to the acoustic envelope of the speech, after characterizing it along five different dimensions that proposedly might affect neural encoding of real-life speech. These included: lexicality, clause-boundaries, clause-duration, speech fluency, and syntactic complexity. Results of the speech-tracking analysis yielded robust TRFs in fronto-central electrodes with four prominent components, which we term the TRF-P50, TRF-N100, TRF-P2, TRF-N350 (reflecting the polarity and latency of each component). Importantly, all of these components were modulated by the speech features we examined, with the most prominent effects found for the later TRF-N350 component. The lexicality of utterances (proper words vs. fillers and mazing) mainly affected the late TRF-P2 and TRF-N350 components, which were mostly absent for non-lexical utterances. Words that constitute clause boundaries (opening vs. closing words) also showed modulation of the TRF-P2 and TRF-N350 components. Clause duration affected the latency of the TRF-N350 response, and modulated the amplitude of earlier components. Syntactic complexity of a clause also affected the amplitude of the TRF- N350, with larger responses to high-complexity vs. low-complexity clauses. Speech rate, however, did not seem to have a prominent effect on the speech-tracking response. In conclusion, the current work demonstrates the importance of acknowledging the complexity of real-life speech. Incorporating the features of real-speech into speech-tracking models will bring about a more ecological understanding of how the brain processes and encodes speech, and deals with its inherent complexities and disfluencies. Our results point specifically to the late TRF components which seem to be sensitive to the non-uniformities and linguistic complexities of spontaneous speech. This suggests that they may be the ‘continuous-speech correlates’ of the well-studied P2 and N400 ERP components in more traditional neurolinguistic research. We hope that this proof-of-concept study will provide the foundation for developing more specific models for studying neural processing of ecological real-life speech.

Topic Areas: Speech Perception; Perception: Auditory

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Neural mechanisms of non-canonical sentence comprehension: A study of effective connectivity in healthy adults

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Introduction. Neurocognitive models of sentence comprehension1-4 involve similar left hemisphere (LH) regions but differ in the role assigned to such regions in processing syntactically complex (non-canonical, e.g., Theme-Verb-Agent) sentences, and in the way regions are inter-connected. During sentence comprehension, healthy adults employ an Agent-first strategy5 that ensures successful comprehension of canonical (Agent-Verb-Theme) sentences, but fails for non-canonical sentences, triggering reanalysis/revision processes. The present study evaluated four neurocognitive models of sentence comprehension1-4 with respect to their ability to predict neural connectivity within the LH language network during comprehension of non-canonical sentences, using Dynamic Causal Modeling (DCM), a hypothesis-driven approach that estimates task-induced neuronal interactions. Methods. Twenty-one right-handed healthy adults (aged 24-61 years) performed a sentence comprehension fMRI task where they indicated whether spoken sentences matched/mismatched concurrently presented pictures of semantically reversible actions. Task conditions included: (1) canonical sentences; (2) non-canonical sentences; and (3) a control condition (reversed speech and scrambled images). DCM models included six LH regions of interest (ROIs) common to all four neurocognitive models: Inferior Frontal Gyrus pars triangularis and pars opercularis (IFGtri and IFGoper), posterior Superior Temporal Gyrus (pSTG), posterior Middle Temporal Gyrus (pMTG), Angular Gyrus (AG), and Anterior Temporal Lobe (ATL). Within each ROI, significantly active clusters (p<.05, uncorrected) for the sentences > control contrast were identified, and participants' timeseries were extracted from 4mm-radius spheres centered on the peak coordinates of the cluster (k>=10) with the highest t-value, adjusted for effects-of-interest. Six participants were excluded because at least one ROI had suprathreshold voxel-wise activation <10 voxels. All DCM models assumed intrinsic connectivity between all regions. Driving inputs reflected sentence comprehension (canonical + non-canonical), and modulatory effects on between-region connectivity reflected syntactic complexity (non-canonical > (canonical + control)). Models were specified as bilinear and deterministic, with two-state neuronal equations employed to model excitatory and inhibitory effects within regions. Fifteen DCM models, reflecting the 4 main neurocognitive models of sentence comprehension and their variations, were compared using random-effect Bayesian Model Selection. Results. The group data was best fit by Bornkessel-Schlesewsky & Schlesewsky's model4, which assumes driving inputs to pSTG and ATL, i.e., the starting point of the dorsal and ventral streams, respectively. In the dorsal stream, following segmentation of the auditory input (pSTG), the sentence syntactic structure is computed (pMTG) and thematic roles are mapped (AG). In the ventral stream, semantic representations for each word are activated and concatenated in the ATL. Both streams converge on the IFG for integration and control processes. Results showed that syntactic complexity modulated the inhibitory connection from the pMTG to AG, suggesting that for non-canonical sentences, sentence structure building (pMTG) results in inhibition of canonical thematic mapping (AG) and subsequent release of the inhibitory constraint from AG to IFGoper, ultimately increasing cognitive control and initiating revision processes. References. 1. Friederici, 2012, Trends in Cognitive Sciences, 16(5), 262-268. 2. Matchin & Hickok, 2020, Cerebral Cortex, 30(3), 1481-1498. 3. Thompson & Meltzer-Asscher, 2014, Structuring the Argument, 141-168. 4. Bornkessel-Schlesewsky & Schlesewsky, 2013, Brain & Language, 125(1), 60-76. 5. Mack & Thompson, 2017, JSLHR, 60(5), 1299-1315.

Topic Areas: Speech Perception; Syntax

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Towards an electrophysiological hallmark for agents vs. patients in working memory *Sandbox Series*

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Events, whether perceived visually or described linguistically, appear to be encoded by humans with conceptual relations to participant roles like “agent” (the “doer” of an action) or “patient” (the “receiver” of an action). For instance, when viewing a visual scene in which a cat is chasing a dog, or comprehending a linguistic expression that “a dog is being chased by a cat”, one can conceptually represent that the cat is the agent, and the dog is the patient. Where and how the brain represents abstract conceptual features such as agent and patient and binds them to mental model representations is still elusive. In the current (ongoing) experiment, we aim at identifying the EEG/ERP signatures distinguishing the encoding of conceptual agents vs. patients. In the current experiment, we employ a novel method inspired by a “pinging” paradigm used in vision neuroscience to study the content of working memory (e.g., Wolff et al., 2017). Participants’ task was to judge the fit between a drawing of an event (presented for 600 ms, e.g., a lion hitting an elephant; Hultén et al., 2014) and a matching/non-matching linguistic expression presented 1700 ms after the offset of the drawing (e.g., “The elephant was hit by the lion”/“The lion was hit by the elephant”, in Chinese; in total 72 trials, involving 4 unique animals and 6 actions). In between the drawing and the sentence judgment (900 ms after drawing offset), we “ping” the agent or patient entity in working memory by briefly flashing (200 ms) the corresponding word (e.g., “lion” with a larger font size). In this way, we are able to “highlight” the agent-entity binding or the patient-entity binding selectively in the ad hoc conceptual structure of the event. By comparing the EEG/ERP upon the presentation of the ping, we are able to compare the EEG/ERP component corresponding to agents vs. patients. We used both active and passive sentences for the match task, in order to encourage conceptual representation of the event and not mere linguistic prediction during the delay interval. We also included a baseline condition where no event was depicted in the picture (72 trials, where e.g., the lion and elephant are simply standing beside each other). Although this search for an EEG/ERP index of event role binding is exploratory, one hypothesis is that it may share features with EEG/ERP components associated with numerical magnitude representations (e.g., Spitzer, Waschke & Summerfield, 2017; Luyckx et al., 2019), based on recent converging evidence that (conceptual) event and magnitude representation both involve human posterior parietal cortex (event: e.g., Thompson et al., 2007; Centelles et al., 2011; magnitude: e.g., Bueti & Walsh, 2009; Summerfield, Luyckx & Sheahan, 2020). Data collection for this experiment is still ongoing, and we are expecting to be able to present some preliminary data by SNL 2021.

Topic Areas: Meaning: Combinatorial Semantics; Methods

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Demographic, Health, and Neural Factors Associated with Chronic Aphasia Severity

Lisa Johnson[1], Alexandra Basilakos[1], Sameneh Nemati[1], Chris Rorden[1], Roger Newman-Norlund[1], Leonardo Bonilha[2], Argye Hillis[3], Gregory Hickok[4], Julius Fridriksson[1]; [1]University of South Carolina, [2]Medical University of South Carolina, [3]Johns Hopkins University, [4]University of California, Irvine

Introduction Lesion size and location are often reported as the most reliable factors that predict severity of language impairment in persons with post-stroke aphasia. Several studies have also found that demographic and health factors are related aphasia severity. The extent to which these factors predict language impairment, beyond traditional cortical measures, remains unknown. Identifying and understanding the contributions of factors to predictive models of severity constitutes critical knowledge for clinicians interested in charting the likely course of aphasia in their patients and designing effective treatment approaches in light of those predictions. Methods Utilizing neuroimaging and language testing data from 224 individuals with chronic aphasia, we conducted a lesion symptom mapping analysis (LSM) to identify regions which predict overall aphasia severity scores. We used residual values from a linear model between severity and proportion damage to these critical regions as the dependent factor in three models: 1) Demographic Model; 2) Health Model; and 3) Overall Model. Results Two regions were identified to be associated with aphasia severity: left posterior insula and left superior longitudinal fasciculus. The Demographic Model revealed cognitive reserve and time post-stroke as significant predictors of severity ($p = 0.004$; $p = 0.03$), and the Health Model found that the extent of periventricular hyperintensities was associated with severity ($p = 0.01$). An interaction between presence of diabetes and exercise frequency was also found ($p = 0.04$), indicating that those with comorbid diabetes who exercise more had less severe aphasia than those who do not exercise. Finally, the Overall Model showed a relationship between aphasia severity and time post-stroke ($p = 0.02$), periventricular hyperintensities ($p = 0.001$), and a significant interaction between diabetes and exercise frequency post-stroke ($p = 0.03$). Summary Results from this study add to the growing literature suggesting demographic variables can shed light on individual differences in aphasia severity beyond lesion profile. Additionally, our results emphasize the importance of cognitive reserve and brain health in aphasia recovery.

Topic Areas: Disorders: Acquired; Language Production

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Disruption of inter-hemispheric, homotopic functional connectivity in post-stroke and progressive aphasia

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A large number of studies have reported strong, synchronized neural activity both at rest and during task performance between homologous regions of the left and right hemispheres. While the function/s of homotopic functional connectivity (FC) are not well-understood, the degree of synchronization has been associated with performance on cognitive tasks and has been reported to be disrupted in a number of brain disorders (see Jin et al., 2020, for a review). Siegel et al. (2016) reported that reduced homotopic functional connectivity was a key feature subsequent to stroke, a finding confirmed by Tao & Rapp (2020). In this research we examined the extent to which homotopic FC patterns reflect disruption to underlying gray and/or white matter structures in post-stroke aphasia (PSA) and primary progressive aphasia (PPA). Methods: We examined resting-state fMRI in 18 individuals with PSA, 18 with non-fluent PPA, and 14 age-matched healthy controls (HC). PSA and PPA groups were matched in age, education, gender and damage epicenter (left inferior frontal lobe). Functional connectivity between the 43 pairs of homologous cortical regions from the AAL atlas were calculated for each participant. First, we evaluated group differences in the average homotopic connectivity strength across all the homologous pairs. Then the connectivity strengths of each homologue pair were compared, with results FDR corrected for multiple comparisons. Results: In terms of average homotopic FC, the PSA group exhibited significantly lower average values than the HCs (p=0.0023), while the PPA group exhibited significantly higher homotopic FC than the HCs (p=0.0011). In terms of individual homotopic connections, we found that for the PSA group, abnormally diminished homotopic FC was concentrated in perisylvian regions (e.g., insula, STG) while for the PPA group, abnormally elevated homotopic FC was concentrated in frontal areas and cingulate cortex. Summary: One hypothesis is that the disruptions to homotopic functional connectivity observed following neural injury are the direct result of structural damage to the gray and white matter substrates specifically involved in the communication between homologous regions. However, we report findings that represent a challenge to this hypothesis. We found that despite having very similar lesion epicenters and damage distributions, post-stroke and progressive aphasia groups exhibited opposite patterns of homotopic disruption relative to healthy controls, with PSA exhibiting significantly reduced homotopic FC, while individuals with PPA exhibited significantly increased homotopic FC. In addition, the specific distribution of disruption across homotopic regions was mostly non-overlapping for the two groups. These findings provide important constraints on hypotheses and form the basis for further investigation regarding the structural and/or functional origins of homotopic FC disruption and the role that these strong inter-hemispheric relationships play in language processing.

Topic Areas: Disorders: Acquired; Language Production

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Cerebello-cerebral resting state functional connectivity in post-stroke aphasia

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INTRODUCTION: Resting state fMRI (rsfMRI) is an emerging method to understand network pathology in post-stroke aphasia (Klingbeil et al., 2019). Previous rsfMRI investigations indicate that disrupted functional connectivity across a distributed network of language and cognitive regions correlate with loss of language function post-stroke (e.g., Sebastian et al., 2016; Sandberg et al., 2017; Zhao et al., 2018). However, the influence of cerebello-cerebral resting state functional connectivity in aphasia recovery is poorly understood. The right cerebellum is a critical region involved in a broad range of language and cognitive functions (Marien et al., 2014). This study investigated the relationship between post-stroke naming deficits and cerebello-cerebral resting state functional connectivity. We hypothesized that weak resting state functional connectivity (low correlations) between the right cerebellum and the left hemisphere would be associated with poorer naming performance. METHODS: Twenty-six, right-handed participants (8 F, 18 M) with chronic (< 6 months post stroke) aphasia due to left hemisphere stroke were included in this study (mean age= 58.7 years). All participants underwent language testing including the short version of the Boston Naming Test (Mack, et al., 1992). Resting state scans were acquired on a Philips 3T scanner. Image preprocessing and statistical modeling were performed using the CONN toolbox implemented in MATLAB (Whitfield-Gabrieli & Nieto-Castanon, 2012). We conducted ROI-to-ROI analyses with a priori regions of interest (ROI) as the seed regions. The ROIs consisted of regions that comprise the language networks, including: right cerebellar Crus I, language seed ROI (Stoodley & Schmahmann, 2009); right cerebellar Crus II (Cereb2); bilateral cerebellar lobules seven (Cereb7) and eight (Cereb8); middle frontal gyrus (MidFG); inferior frontal pars opercularis (IFG oper) and pars triangularis (IFG tri); anterior and posterior superior temporal gyrus (STG), anterior and posterior middle temporal gyrus (MTG), anterior and posterior inferior temporal gyrus (ITG), angular gyrus (AG); anterior and posterior supramarginal gyrus (SMG); and lateral occipital cortex (LOC). Single-subject baseline functional connectivity parameters were extracted from CONN for each ROI that showed significant connectivity with the seed ROI and used as independent variables in a multiple linear regression model associating Boston Naming test score with baseline functional connectivity. RESULTS: Baseline functional connectivity analyses showed positive correlations between the right cerebellar Crus I and left cortical regions: ITG, SMG, LOC, and MTG. In multiple linear regression, controlling for time post stroke, age and lesion volume, baseline functional connectivity between right cerebellar Crus I and both the left anterior ITG (Beta = -22.52, $p = 0.008$) and right Cereb2 (Beta= 16.44, $p= 0.021$) were significant predictors of Boston Naming Test score. The overall model fit was $R2 = 0.521$ ($p= 0.008$). Left SMG, LOC and MTG were not significant predictors. CONCLUSION: These results suggest that cerebello-cerebral resting state functional connectivity may be an important factor in post-stroke aphasia recovery. As previous studies have mainly assessed cortical connectivity alone, this investigation proposes that functional connections between the right cerebellum and residual left hemisphere regions may also play a role in predicting naming ability post-stroke. Acknowledgements: NIH (NIDCD), R00 DC015554.

Topic Areas: Disorders: Acquired; Language Therapy

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Effects of transcranial alternating current stimulation (tACS) on language and network coherence in aphasia *Sandbox Series*

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Background Approximately 20-35 percent of stroke survivors experience aphasia, a language disorder resulting from damage to language regions of the left hemisphere (LH). Nonfluent aphasia (NFA) is one of the most common subtypes of aphasia, a language disorder resulting from damage to language regions in the left hemisphere (LH). NFA is particularly resistant to treatment, with nonfluent speech being one of the most refractory symptoms. A treatment paradigm called speech entrainment (SE), established by our group facilitates fluent speech production in NFA (Fridriksson et al., 2012; 2015) and improves anterior-posterior LH functional connectivity between hubs deemed ‘critical’ for successful entrainment (Johnson et al., under review; Bonilha et al., 2019) . As an adjuvant to behavioral approaches for rehabilitation, noninvasive brain stimulation (NIBS) techniques improve therapy outcomes (Baker et al., 2010; Fridriksson et al., 2011; Fridriksson et al., 2018; Meinzer et al., 2016; Marangolo et al., 2014). One NIBS method, transcranial alternating current stimulation (tACS), is unexplored as a method to boost aphasia therapy outcomes. tACS is hypothesized to entrain endogenous rhythms at the frequency of stimulation (Ali et al., 2013; Herrmann et al., 2013) and induce synaptic changes via spike timing dependent plasticity (Vossen et al., 2015; Zaehle et al., 2010) to modulate behavioral effects. The current study aims to determine if tACS will improve SE performance among individuals with chronic NFA. Methods In a proof-of-concept study, transcranial alternating current stimulation (tACS) will be paired with SE in a cohort of 20 patients with NFA in a within subjects, double-blind study. 1 mA of tACS at a frequency of 7 Hz (theta frequency) will be applied to perilesional LH anterior and posterior regions to modulate network coherence across three conditions: 1) in-phase; 2) out-of-phase; and 3) sham while participants mimic an audiovisual model (SE). The primary aims of the current investigation are as follows: 1) Does tACS boost behavioral outcomes (as measured by speech fluency: different words per minute) as compared to performance in the sham and out-of-phase conditions? 2) To what extent does stroke-induced damage (as measured by lesion characteristics [proportion of damage] and neural connectivity [structural/functional]) predict behavioral responses to tACS? Results Pilot data for this study will be collected throughout the summer of 2021 and preliminary behavioral and neuroimaging results will be presented at the SNL 2021 Conference. It is hypothesized that tACS will provide an exogenous boost of in-phase frontotemporal theta coupling to enhance frontotemporal network connectivity, facilitate neural integration, and subsequently, improve SE performance. We predict that a greater proportion of spared frontotemporal cortical regions will yield better modulatory effects of neural coherence for improved behavioral outcomes. Conclusion There is a critical need for effective and efficient rehabilitation paradigms to treat poststroke aphasia. Supplementing an evidence-based behavioral paradigm with a novel application of NIBS to modulate LH network coherence may yield a more efficient application of this behavioral therapy. Pilot data will contribute to the growing body of research investigating noninvasive brain stimulation as an adjuvant to traditional speech-language therapy.

Topic Areas: Disorders: Acquired; Language Therapy

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Right hemisphere structural connectivity predicts naming outcomes in chronic aphasia *Sandbox Series*

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Background Aphasia is a language disorder resulting from damage to eloquent language regions in the left hemisphere (LH). Diffusion tensor imaging (DTI) assesses the microstructural integrity of white matter pathways in the brain. Most DTI studies in aphasia focus on network connectivity in the LH and suggest that damage to LH structural connections in remote regions may substantially impact language in the chronic stages (Yourganov et al., 2016; Bonilha et al., 2014). Fewer investigate connections between right hemisphere (RH) homologues (Wan et al., 2014; Schlaug et al., 2009; Pani et al., 2016; Keser et al., 2019). The role of the RH in recovery, and the interaction with LH integrity, remains inconclusive and it is still unclear which neural mechanisms support aphasia recovery. The aim of the current study is to determine if RH structural connectivity is associated with naming outcomes in poststroke aphasia. To do this, we model severity at two different time points and then model longitudinal changes across these time points. Methods First, we used baseline DTI data and naming abilities (as measured by the Philadelphia Naming Test; Roach et al., 1996) at two time points: baseline ($n = 101$) and six months ($n = 80$). NiiStat toolbox (https://www.nitrc.org/projects/niistat/) was used to conduct DTI analyses ($p < 0.05$, correction for multiple comparisons with permutation thresholding [5000 permutations]). To control for the LH lesion, we regressed out damage to LH dual stream regions (sum of proportional damage to dorsal and ventral regions; Fridriksson et al., 2016) using the AICHA atlas (Joliot et al., 2015). Next, longitudinal differential tractography was performed using DSI Studio (http://dsi-studio.labsolver.org/) between baseline and 6-month DTI scans (Yeh et al, 2013). Changes in naming scores were calculated as proportion of maximal gain (PMG): (score at 6 months-baseline)/(maximum score-baseline). Tracking only occurs along trajectories where changes in anisotropy are apparent between repeat scans in the same individual. PMG scores were associated with these connectomes using correlational tractography. Results Naming performance at baseline was predicted by the integrity of structural connections between anterior and posterior RH homologues (IFG : Middle Occipital Gyrus (MOG), $z = 4.33, 4.62$; MOG : Anterior Insula, $z = 4.24$; MOG : Superior Temporal Gyrus (STG), $z = 3.93, 3.91$; Anterior Insula : STG, $z = 4.31$). Similar RH anterior-posterior connections predicted outcomes at six months. Longitudinal connectometry analyses revealed that connectivity in the RH inferior longitudinal fasciculus (ILF) positively correlated with change in naming performance between baseline and 6-months ($p < 0.01$). Conclusion Results suggest that the integrity of RH anterior-posterior homologue regions and the structural connections between them are correlated with naming at baseline and six months post-treatment. Consistent with this, longitudinal analyses reveal the right ILF positively correlates with change scores. Results are largely consistent with a recent study examining similar associations in subacute aphasia (Blom-Smink et al., 2020). Determining the role of the RH, or more broadly, considering predictive neural mechanisms that may predict language outcomes in chronic aphasia, will be important to advance treatment modalities for aphasia.

Topic Areas: Disorders: Acquired; Methods

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Supplementary motor area first predicts reaction time in stereotyped word articulation in large-scale intracranial EEG *Sandbox Series*

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Single-word production, especially in the context of picture naming, has long been used to probe the neural networks underlying our uncanny ability to retrieve and produce specific lexical items from a large vocabulary. To characterize the articulation-related portions of these networks, we used intracranial recordings from a large cohort (134 epilepsy patients) performing multiple repetitions in which they articulated a single word, 'scrambled,' on average 66 times. The 25,000+ electrodes (subdural grids as well as depth electrodes) provided comprehensive coverage of language-dominant hemisphere. Using just one word eliminates numerous semantic, lexical, and phonological confounds intrinsic to the analysis of the production of a range of words. Behavioral data showed an average within-patient reaction time of 1137ms with standard deviation of ~300ms. Global mean broadband gamma (BGA) power dynamics, derived using a surface-based mixed-effects multilevel analysis (SB-MEMA), were used to create a 4D representation of cortical dynamics during this single-word production. From the SB-MEMA, we isolated suprasylvian regions of interest (ROIs) to investigate further. Gamma power in supplementary motor area (SMA), preSMA, precentral sulcus, and inferior frontal sulcus reach significance earliest, followed by the central sulcus and IFG. Finally, motor regions (subcentral gyrus and postcentral gyrus) are engaged to produce the appropriate motor gestures. Using these high-temporal resolution dynamics at hand, we sought to explain reaction time variability. We modeled reaction time as a function of BGA across trials at various time points across the pre-articulatory window. Activity of the supplementary motor area was the earliest predictor of reaction time, reaching significance just 250ms after stimulus onset. In contrast, activity in other early-onset ROIs, such as IFS and precentral sulcus, are not predictive of reaction time until 300ms after stimulus onset. In a final set of analyses, we used linear mixed-effects analyses to model reaction time per trial as a function of whether or not the trial was preceded by a 'scrambled' trial (PRIMED), the number of cumulative SCRAMBLED trials, and the number of trials since the previous SCRAMBLED trial, and implant type (SEEG or SDE). Each of these predictor variables were significant. Only PRIMED and implant type had a notable effect size (87 and 134ms, respectively). To identify a cortical correlate of the reaction time decreases in the PRIMED condition, we tested each active electrode in each ROI for BGA power divergence between the two conditions. 13 of 637 recording sites showed a 'preference' for either the PRIMED or UNPRIMED conditions when time-locking to stimulus onset. Taken together with the finding that SMA best predicts reaction time, reaction time decreases in the PRIMED condition may be primarily driven by subcortical structures with sparse cortical effects discernible with priming. SMA-mediated cortical-basal ganglia-thalamus loops may be initiated sooner for PRIMED trials that require a re-execution of a motor program as opposed to motor program selection and execution in UNPRIMED trials. Overall, this work highlights the key role of the SMA in speech initiation and timing and elaborates in detail the global networks involved in overlearned articulation.

Topic Areas: Language Production; Control, Selection, and Executive Processes

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Error detection and correction among adults with aphasia in a naming task *Sandbox Series*

Jeremy Yeaton[1], Grant Walker[1], Julius Fridriksson[2], Gregory Hickok[1]; [1]University of California, Irvine, [2]University of South Carolina

Introduction. Picture naming deficits are a common symptom of stroke-induced aphasia. The Philadelphia Naming Test (PNT; Roach et al. 1996) is a commonly used tool in assessment of such deficits. The test comprises 175 line-drawings of concrete imageable nouns, which a participant is asked to name out loud. The first and last (if more than one was made) naming attempt are recorded. A clinician codes the responses by type (e.g.: correct, semantically related, neologism). While previous research has primarily focused on the first complete response, by taking a closer look at secondary attempts to correct errors, we can gain insight into error detection and correction abilities in aphasia. In this work we examine what variables impact error detection (operationalized as whether an attempt to correct was made), and correction attempt outcomes in two cohorts of participants with aphasia. We find that rather than demographic variables, cognitive psychometric model parameters can best predict naming error detection and correction. Participants. Our population includes a total of 156 participants across two cohorts for whom we had complete datasets (n=70 [31F, mean age=60.73 (11.7)] & n=86 [35F, mean age=60.79 (11.1)] respectively). Method. For both groups, we had demographic variables (age at test, months post stroke, gender, ethnicity), clinical variables (aphasia type diagnosis, Western Aphasia Battery (WAB; Kertesz, 2006) aphasia quotient (AQ)) and modeled variables derived from a cognitive psychometric Multinomial Processing Tree (MPT; Walker et al. 2018) model of naming. For each participant, the MPT-Naming model outputs estimates of latent abilities critical to successful naming (Semantic, Lexical-Semantic, Lexical-Phonological, Lexical Selection, Phonological), estimated from the set of first complete attempts. We fit a random forest classifier to identify which variables are useful in predicting a) whether a correction attempt was made after an error, and b) whether such an attempt was successful. Using a Boruta test on the classifier, we identified which variables contribute to classification accuracy (Kursa et al., 2010). We used a p-threshold of 0.01, and Gini impurity as our importance metric (D'Ambrosi & Tutore, 2011). Results. We found that the Lexical-Semantic MPT parameter was the only significant predictor of whether a second attempt would be made, and, using only this predictor, 75.5% of out-of-bag items could be classified successfully (including all variables resulted in a 0.6% gain in accuracy). We found that the Semantic, Lexical-Phonological, and Phonological MPT parameters as well as the WAB AQ were significant predictors of second attempt success. This set of variables achieved 78.9% accuracy. Including the rest of the variables resulted in a 0.7% gain in accuracy. Discussion. Different naming abilities, operating at different psycholinguistic levels of representation (lexical versus sublexical), were predictive of whether secondary naming attempts were made and whether they were successful. Neurobiological mechanisms underlying this cognitive dissociation are considered with respect to lesion patterns associated with the relevant abilities identified in previous work (Walker, 2019). Lexical-semantic abilities were associated with temporal regions (ventral stream) while phonological abilities were associated with auditory-motor and primary motor regions (dorsal stream) (Hickok & Poeppel, 2000).

Topic Areas: Disorders: Acquired; Language Production

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Establishing the link between speech to speech synchrony and general auditory-motor synchronization skills *Sandbox Series*

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Auditory-motor synchronization (AM-synch) is the ability to temporally align a train of motor gestures to a rhythmic auditory stimulus. In humans, it is an innate skill that has been shown to predict performance on different language-related tasks; across species, it has only been observed in vocal learners. In light of this link between AM-synch and speaking abilities, Assaneo and colleagues explored the phenomenon in the context of speech. They designed a behavioral protocol, the Spontaneous Speech Synchronization Test (SSS-test), in which participants are instructed to continuously repeat the syllable “tah” while concurrently listening to a rhythmic train of syllables. Using this simple test showed that the general population can be segregated into two groups: while some participants are compelled to spontaneously align the produced syllabic rate to the perceived one (high synchronizers), the rate of other participants is not modulated (low synchronizers). Strikingly, individuals classified as ‘high’ or ‘low’ synchronizers have structural and functional brain differences, with important consequences regarding speech processing and language learning skills. This initial work invites the following questions: where does the predictive power of the test come from? Is the bimodal distribution of the synchronization measurement a consequence of the speech motor gestures or the acoustic properties of the stimulus? To answer these questions, in the present study we evaluate the level of AM-synch for different motor gesture-stimulus combinations. Motor gestures, as well as the stimulus, can be speech-related (whispering “tah”/train of syllables) or speech-unrelated (clapping/train of tones). Participants completed eight synchronization blocks, two for each motor gesture-stimulus combination. On each block, participants were instructed to continuously repeat the motor gesture (whisper or clap) at the same rate as the auditory stimulus (train of syllables or train of tones) until the end of the stimulus. All stimuli lasted 1 minute, the rate started at 4.3 Hz (i.e., 4.3 syllables or tones per second) and it increased in 0.1 Hz every 10 seconds until it reached 4.7 Hz. Preliminary results show that, while the bimodal distribution is recovered for the clapping-to-syllables combination, it dissolves (most participants were able to synchronize) when the stimulus included tones, regardless of the motor gesture. This result shows that the previously reported ‘high’ vs. ‘low’ synchronizers segregation is a consequence of the acoustic features of the stimulus and is independent of the nature of the motor response. Additionally, individuals classified as low synchronizers during a first assessment with the SSS-test, show a significant increase of their synchronization abilities to the train of syllables, when the SSS-test is completed after the clapping to tones block. This suggests that synchronization abilities can be temporarily enhanced if previously entrained by a more efficient stimulus. Building upon these results, further work will be conducted to identify the precise acoustic characteristics that would grant the previously observed bimodal outcome in the synchronization test and to explore whether a temporal enhancement of synchronization abilities translates to better performance in language-related tasks.

Topic Areas: Multisensory or Sensorimotor Integration; Speech Motor Control

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Functional network changes in post-stroke and primary progressive aphasia: Shared and distinctive features

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Very similar aphasia profiles can result from stroke (PSA) and neurodegenerative diseases (e.g., primary progressive aphasia -- PPA). However, it is not known whether the two aphasia etiologies produce similar functional network disruption. Moreover, it is not understood how the different temporal characteristics of the etiologies (static, focal vs. progressive) affect functional network (re)organization. To address this issue, we compared the functional network properties of PSA and PPA using graph-theoretic methods. Importantly, both groups had overlapping damage epicenters (left inferior frontal lobe) and language characteristics, allowing us to attribute functional network differences to the different pathological processes. Methods We examined resting-state fMRI in 18 individuals with PSA, 18 with non-fluent PPA, and 14 age-matched healthy controls (HC). PSA and PPA groups were matched in age, education, gender and damage epicenter. Functional connectomes were constructed for each participant and for each hemisphere (LH connectome: 111 nodes, RH connectome: 122). Nodes with substantial damage in each participant were excluded. We examined the graph-theoretic metrics: normalized global efficiency (GE) and clustering coefficient (CC), calculated from binary graphs with fixed edge density (10%-40). GE quantifies the extent of global integration of nodes, with higher values indicating that, on average, fewer steps (connections) separate each node from every other node. CC measures local functional integration, with higher average values indicating greater pervasiveness of small cliques (triangles). First for both measures we carried out a mixed-effects regression analysis to compared the hemisphere averages of each aphasic group to the HC's and evaluated if effects were consistent across hemispheres. Second, in regional analyses, we investigated whether hemispheric effects were driven by the GE and CC characteristics of specific brain regions. Results In terms of average hemispheric effects we found: (1) for GE, both aphasic groups had similarly lower values than HCs in both hemispheres (PSA: $p=0.08$; PPA: $p=0.07$); (2) For CC, there was a hemisphere-by-group interaction with normal CC levels in the LH (HC-PSA: $p=0.68$, PPA $p=0.43$) but significantly higher levels in the RH (HC-PSA: $p=0.05$, PPA: $p=0.0008$). The results revealed that both aphasic groups exhibited more segregated, less integrated functional network organization, not only in the lesioned left hemisphere but also in the right. In terms of regional effects, we found: (1) In terms of GE, for PSA lower values were concentrated in LH peri-lesional and in RH contra-lesional areas. In contrast, for PPA, decreased GE was observed in bilateral dorsal parietal areas; (2) With regard to CC, for PSA, increases were concentrated in contralesional RH areas. Summary Despite very similar lesion foci, both PSA and PPA groups exhibited very distinctive regional effects. This suggests that functional network changes in PSA may be driven by the focal and static nature of the damage to neural tissue whereas in PPA the temporally extended time-course of the disease may play a critical role. Nonetheless, changes in both aphasia types resulted in overall more segregated, less integrated networks, which may reflect a common re-organization mechanism in response to neural injury, regardless of etiology.

Topic Areas: Disorders: Acquired; Computational Approaches

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A retrospective comparison of language lateralization as assessed with the Wada test and functional MRI *Sandbox Series*

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There is considerable variability between individuals in the extent of activity observed in the subdominant hemisphere when language areas are mapped with fMRI, with some individuals demonstrating a complete absence of activity and others demonstrating activity similar to that of the dominant hemisphere [1]. It has been speculated that this variability in subdominant activation may explain recovery patterns in post-stroke aphasia [2], and a transcranial magnetic stimulation (TMS) study showed that subdominant activity in neurologically normal individuals was protective when a virtual lesion was created in the dominant hemisphere [3]. Does the presence of activation in the subdominant hemisphere reflect an independent ability of that hemisphere to process language? In this “sandbox series” presentation, we describe our plans to address this question using a retrospective comparison of fMRI and Wada findings [4] obtained as part of presurgical workups for epilepsy and brain tumor patients. The Wada test provides a measure of the independent linguistic capacity of each hemisphere. Specifically, we plan to ask the following primary question: is there a correlation between subdominant hemisphere activation on fMRI and that respective hemisphere’s demonstrated independent capacity during the Wada test? Results from the Wada test in the medical record are typically recorded in narrative form, documenting whether or not patients are able to complete various language tasks when each hemisphere is anesthetized (e.g., follow one–step commands, follow two–step commands, name objects, etc.). In order to quantify the results from the Wada test to be used in a statistical analysis, we developed a coding scheme in which receptive and expressive language are rated separately. Receptive language is rated on a 0–2 scale, and expressive language is rated on a 0–3 scale. From the fMRI data, lateralization indices will be calculated to quantify the relative levels of activity in each hemisphere. Because we are using archival fMRI protocols that have not always had tightly controlled baselines, we plan to use language area masks to exclude potentially confounding sensorimotor activations. We have a working cohort of 92 participants who have undergone both fMRI and the Wada test. At the present time, we have coded the Wada results from 54 participants. Of these 54, 43 have demonstrated independent language ability in just one hemisphere, 6 have demonstrated at least partial ability in both hemispheres, and 5 did not show independent capacity for language in either hemisphere. After we complete coding of the Wada studies and analysis of the fMRI data, we will determine whether activation in the subdominant hemisphere observed on fMRI is associated with independent capacity for language processing by the subdominant hemisphere. This study may provide insight into the role of the subdominant hemisphere in recovery from aphasia following damage to the dominant hemisphere. [1] Wilson et al. Hum Brain Mapp 2018; 39: 3285-307. [2] Crinion & Price. Brain 2005; 128: 2858-71. [3] Knecht et al. Nat Neurosci 2002; 5: 695-9. [4] Wada & Rasmussen. J Neurosurg 1960; 17: 266-82.

Topic Areas: Disorders: Acquired; Methods

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The Triplets Task: a open, large scale, curated benchmark for biological and artificial semantic representations (in the making) *Sandbox Series*

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Current theories of semantic knowledge aim at capturing how specialized yet distributed neural representations can encode both experiential (e.g., the word lemon evokes the concept of sour) and distributional (e.g., the word lemon often comes with squeezer) information [1,2]. Moreover, given the increasingly widespread adoption of natural language processing (NLP) models as a window onto the neuro-cognitive correlates of human language processing, the field is in need of appropriate benchmarks to compare artificial and human semantic representations. We set out to validate a task testing how well different neuro-cognitive and NLP models predict human behavior. Modeled on common neuropsychological tests of associative semantic knowledge, we devised a task eliciting human participants' semantic representations by asking which of three words are more closely associated (e.g., lemon / squeezer / sour). We then generated 10k of triplets of both abstract and concrete nouns (6433 unique words) and compared how they would be solved by experiential and distributional models. We selected one neuro-cognitive model embedding concepts onto 11 sensory-motor dimensions (the Lancaster Sensorimotor Norms, LSN [3]) and fourteen NLP models: five GloVe models trained on Wikipedia, four GloVe models trained on Twitter, a sense2vec model trained on Reddit comments, a fasttext model trained on Common Crawl, and three fasttext models trained on Amazon reviews, Yahoo answers, and Yelp reviews respectively. Overall, NLP models agreement ranged from perfect (100%) to null (0%), with a mean of 40.94 (std = 25.05), while NLP models and LSN had only a 30% agreement. We then selected a subset of triplets (n=2555, 3630 unique words) for online behavioral validation. We chose those triplets that (1) had been evaluated by at least 6 models; (2) appeared in LSN; (3) showed the highest (i.e, < 25%, n=2078) or lowest (i.e, > 75%, n=477) level of agreement among NLP models. To date, we collected responses from 1292 MTurk workers (555 female, 103 left handed, mean age 39.66±11.32 y; mean education 15.39±1.8 y). Our preliminary results suggest that LSN captures human semantic representation better than the NLP models (percentage agreement 73.5% vs. 23.68%). We will openly release the full set of triplets, along with the associated code and behavioral data. Overall, we believe our large, carefully curated, dataset will be a useful benchmark for both computational and empirical investigations of semantic knowledge. The current results suggest that incorporating sensory-motor, experiential information is critical to achieve human-like semantic representations. [1] Bidner 2016 https://doi.org/10.1080/02643294.2016.1147426 [2] Huth 2016 https://doi.org/10.1038/nature17637 [3] Lynott 2019 https://doi.org/10.3758/s13428-019-01316-z

Topic Areas: Meaning: Lexical Semantics; Computational Approaches

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Understanding implausible passives in aphasia: algorithmic and heuristic processes compete *Sandbox Series*

Caitlyn Antal[1], Djuly Trankarov[1], Kyan Salehi[1], Alexa Ray Falcone[1], Laura Pissani[1], Roberto G. de Almeida[1];
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INTRODUCTION Given implausible passive sentences such as “The dog was bitten by the man”, native speakers sometimes report incorrectly that “the dog'' is the doer of the action. Similar effects have been used to illustrate several overlapping accounts of language comprehension such as “pragmatic normalization” (Fillenbaum, 1974), “good enough” interpretation (Ferreira, 2003), and “rational inference” (Gibson et al., 2013). Yet, the nature of these errors in interpretation remains unclear: Is it a failure of grammatical—algorithmic—processes to yield a structure that is faithful to the correct interpretation of the sentence? Is it due to higher-order processes driven by heuristics (e.g., pragmatic) thus neglecting what grammar outputs? Or does the interpretation fail because of a combination of both algorithmic and heuristic processes? Some studies have shown greater difficulty to process implausible sentences in individuals with Broca’s aphasia (e.g., Caramazza & Zurif, 1976) given their difficulty with syntactic (algorithmic) computations. Others, however, suggest that “persons with aphasia in general” (Gibson et al., 2015) have difficulty with implausible sentences due to “greater noise”. We investigated dissociations between sentence type and aphasia etiology aiming to understand the source of implausible passive deficit and what they inform us about the unimpaired language comprehension system. METHOD Participants were 6 non-fluent [NF], 4 fluent [FL], 3 mixed but predominantly non-fluent [MN], 2 with mixed aphasia [MX], and 42 healthy controls. In each trial, a sentence was aurally presented and immediately followed by two pictures on a computer screen. Participants had to choose which picture best represented the sentence they heard. The 24 experimental quartets varied in voice (active, passive) and plausibility (plausible, implausible): (a) active plausible (The dog bit the man), (b) active implausible (The man bit the dog), (c) passive plausible (The man was bitten by the dog), and (d) passive implausible (The dog was bitten by the man). Pictures for the sentences above were that of a dog biting a man (correct for (a) and (c)) and a man biting a dog (correct for (b) and (d)). RESULTS Repeated measures ANOVAs showed a main effect of group, voice, and plausibility, as well as all first and second order interactions. Overall, group analyses showed that NF and MN individuals performed worse than controls on all sentence types. We also found an effect of plausibility, whereby NF and MF individuals had significantly more difficulty choosing the correct picture when presented with implausible sentences. These impairments were not found in FL individuals. Case-series analyses will also be presented. DISCUSSION Our group analyses suggest that the underlying nature of the impairments for NF and MN individuals may stem from a deficit building structures corresponding to event descriptions. The difficulty shown by the NF and MN groups with passive and implausible sentences suggests that they have an impairment computing the syntactic (algorithmic) processes fundamental to language comprehension. We further suggest that this deficit may be coupled with problems computing thematic structures for noncanonical sentences leading to erroneous choices based on heuristic (viz., pragmatic) processes.

Topic Areas: Meaning: Combinatorial Semantics; Disorders: Acquired

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Features, flexibility, and fakes: How modifiers change concepts *Sandbox Series*

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An important question surrounding concepts is whether or not they have “cores” that define them, separate from any features that they may also probabilistically have. Supporters argue that people tend to feel that most things, especially natural kinds and well-defined categories, have a certain essence that causes their category membership even if they lack key features, although they are usually unable to articulate what precisely that essence might be (Gelman, 2004). Detractors point out that most concepts, particularly artifacts, are impossible to define in any meaningful way, and that if concepts have cores but people never use them to recognize, categorize, or reason about objects, then they are essentially useless (Malt & Johnson, 1992). One difficulty with answering this question is that it is possible that all concepts may have distinctive cores. While it is generally accepted that the core of plants and animals would be built around their genetic composition, artifacts could potentially be defined by many things, such as their function, their material, their appearance, or their intended purpose (Barton & Komatsu, 1989; Bloom, 1998), and different artifacts could possess different cores depending on various idiosyncratic factors. To address this problem, we turned to the class of privative adjectives, which satisfy the constraint, “An [adjective] [noun] is not a [noun]” (Partee, 2007). Many of these adjectives, such as fake, false, counterfeit, imitation, mock, faux, etc., explicitly pick out things that are in some way a representation of the original concept (i.e., a decoy duck is a representation of the duck) and thus have many of the same visual features of the original, but are by definition not true examples of the original concept (so a decoy duck is not a duck). Therefore, privative adjectives could consistently negate the cores of concepts regardless of what those cores might be. In one study, participants were asked whether certain modified concepts did or did not belong to the same category as the bare, original concept. A second study had participants rate the likelihood of sentences that followed the form, “[Concept] has [feature].” The sixty-five concepts were either unmodified or modified by fake; a prototypical adjective; a non-prototypical adjective wherein a typical feature was negated; an orthogonal adjective that made the concept neither more nor less typical; or some combination of the modifiers. The features were either visual or internal. Participants were also asked to produce descriptions for several fake concepts. As predicted, all modifiers increased uncertainty for all conceptual features, replicating prior studies on uncertainty under combination (Connolly et al., 2007). However, fake differentially weakened or negated internal features. While the current study does not directly address the existence of conceptual cores, the results do provide support for them, as they suggest that while the boundaries of conceptual categories can be stretched quite far, internal features are what determine category membership. They also suggest that privative adjectives provide a previously unexplored avenue for determining where conceptual boundaries are and what features are most central to particular concepts.

Topic Areas: Meaning: Combinatorial Semantics; Meaning: Lexical Semantics

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The Emergence of the Neural Representation of Novel Words through Narrative Reading *Sandbox Series*

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Learning words is a process that requires gathering cues from the context the word appears in and integrating these cues to build a meaningful semantic representation (Caramazza et al.,1990). Throughout learning selective attention processes are employed in capturing contextual statistical regularities and building meaningful associations for further categorisation of the novel word (Devlin et al. 1998, Nofosky et al, 1986). A wealth of studies show that the successful semantic processing and categorisation of a word is distributed over specific linguistic and sensory-motor systems, to the extent that the category of the word can be reliably predicted from patterns of activations within those brain regions (Mitchell et al., 2008; Huth et al., 2012; Shinkareva et al., 2012). Given the distributed nature of semantic processing, the emergence of the neural representation of a novel word is expected to follow a distributed fashion over the functional areas associated with the processing of the corresponding semantic information. Leveraging known differentiating neural signatures associated with the processing of familiar vs unfamiliar (David & Gaskell, 2009), old vs new (Vuilleumier et al., 2002) and frequent vs infrequent (Fiebach et al., 2002) words, we set out to investigate the emergence of the neural representations of novel words in an experimental setting in which the amount and the sequence of semantic information available were experimentally controlled. We acquired EEG and fMRI data simultaneously from 28 healthy right-handed subjects on a silent narrative reading task. Subjects were trained on a set of sentences introducing three different semantic features (habitat, visual, functional) of a group of made-up and real objects from two semantic categories (tools, animals). Each semantic feature was introduced in a separate block and repeated six times to reinforce learning. Each learning phase was followed by a semantic congruency test to quantify the learning success. Our preliminary analyses of behavioural performance confirm that subjects achieved successful word learning. We will now focus on testing the temporal and topographical hypotheses leveraging the complementary strength of simultaneous recording of the two neuroimaging modality. Our initial aim is to observe the temporal trajectory of the comprehension of the novel word knowledge by investigating one of the well-established neurophysiological markers of the meaning integration, N400, a negative deflecting EEG component following the 400 ms after the stimulus onset. As an indicator of the successful encoding of a novel meaning, we expect to observe a training-related attenuation of the N400 amplitude that is elicited due to the incongruent matchings between the novel word and an unrelated semantic context. Secondly, we expect the emergence of multivoxel activity patterns in a priori defined brain regions based on previous work (i.e. parahippocampal gyrus, precuneus, occipito-temporal gyrus, premotor cortex, left inferior frontal gyrus, fusiform gyrus) (Bauer & Just, 2015; Chao & Martin, 2000; Binder et al., 2009) that follows the sequential introduction of the semantic attributes associated with the novel word, such that it predicts the semantic property and the level of novelty of the information that is encoded.

Topic Areas: Meaning: Combinatorial Semantics; Meaning: Lexical Semantics

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Unique features of brain processing of expletives in naturalistic context *Sandbox Series*

Annette Glotfelty[1], Jeremy I. Skipper[2], Sarah Aliko[2], Steven L. Small[1]; [1]The University of Texas at Dallas, [2]University College London

Expletives (“curse words”, “swear words”, “profanity”, “obscenities”, “taboo words”) have been shown to have unique properties in individuals with neurological disease. Profanity can be a manifestation of vocal tics in Tourette’s syndrome, used as a compensatory technique during stuttering blocks, and preserved in cases of aphasia. Further, uttering such words can increase some people’s pain tolerance. The observed conservation of cursing ability in the presence of even global aphasias with lesions to areas considered critical for language processing (e.g., posterior superior temporal gyrus, posterior inferior frontal gyrus) provides evidence that these words are somehow encoded and/or accessed differently than other types of words in the brain. One explanation for the distinctiveness of such words is that obscenities are emotionally charged, possibly to such an extent that their use in context may approximate non-word emotional utterances such as laughing, groaning, or screaming. However, relatively little neuroimaging evidence is available to inform the neural processes that underpin cursing. This study in its preliminary stages seeks to explore brain dynamic functional connectivity during profanity perception in a rich contextual environment, using fMRI recordings of participants watching full length films from the Naturalistic Neuroimaging Database. By understanding the biological basis of the differential comprehension of this class of utterances, we seek to gain further insights into embodied brain representations of language in healthy individuals and those with neurological disease. Network architecture will be examined for a continuum of emotional vocalizations, from those assumed to be more deliberate to those thought more visceral: words matched by arousal scores, curse words, and non-word emotional vocalizations. Patterns of functional brain activation and connectivity over time will be examined for commonalities and distinctiveness across the conditions. Nascent hypotheses are that network organization along the continuum will begin with putative language regions serving as hubs of high connectivity for matched arousal words, moving toward a model where hubs are based in areas recognized as critical to emotional perception (e.g., limbic regions such as the thalamus and amygdala, limbic-related areas such as the insular cortex) for non-word emotional utterances. We hypothesize that swear words will demonstrate connectivity in voxels that bridge these hubs. A pilot duration-modulated regression was run on 86 participants watching 10 movies. Individual analyses and group t-tests indicated that perceiving an initial subset of expletives in natural context, compared to perceiving words matched on arousal score, showed significantly increased activation in the precuneus, posterior middle temporal gyrus, insular cortex, fusiform gyrus, and periaqueductal gray. ‘Decoding’ resulting regions with Neurosynth indicates that these areas are associated with terms related to social and emotional cognition. We will aim to further improve this model of natural processing of profanity by extending the list of expletives and controls and by performing dynamic functional connectivity analysis. Additionally, findings will be analyzed to determine how semantic context affects the neural processing of obscenities (e.g., swearing during a highly emotional scene vs. cursing as a character’s trait) or how individual differences in participant emotional health (assessed by NIH Toolbox affective batteries) modulate the findings.

Topic Areas: Meaning: Discourse and Pragmatics; Meaning: Lexical Semantics

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Slide Slam Session Q

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Leukoaraiosis and language later in life

Sara Sayers[1], Roger Newman-Norlund[1], Sarah Wilson[1], Nicholas Riccardi[1], Samaneh Nemati[1], Sarah Newman-Norlund[1], Julius Fridriksson[1]; [1]University of South Carolina

Introduction: Leukoaraiosis, or the pathological appearance of white matter hyperintensities (WMHs) resulting from diseases of the small vessels, is thought to be a good indicator of overall brain health. Degeneration of deep and periventricular white matter tracts negatively affects structural connectivity between normally connected brain regions. Increased leukoaraiosis has been reported in dementia, cognitive decline, stroke, and aging. Our prior work in chronic post-stroke aphasia indicates that the extent of leukoaraiosis severity at initial evaluation is predictive of declines in language abilities at follow-up. The current study examined the relationship between leukoaraiosis and language (specifically discourse) in a healthy elderly population. Methods: Sixty participants (60-80 years old) completed the Montreal Cognitive Assessment (MoCA), produced narrative discourse and had MRI testing as a part of the Aging Brain Cohort testing battery at the UofSC. For the MoCA, the total score and six domain-specific index scores were calculated. White matter hyperintensities were manually identified and drawn by two independent, trained raters. WMH load (the percentage of white matter considered to be damaged) was calculated by normalizing the total WMH voxel count by overall brain size. To elicit a discourse sample for analysis, we administered Talkbank's Cat Rescue picture description task. Trained study staff transcribed the video recordings, separated utterances into communication units, and coded the transcripts for specific linguistic variables using the CHAT transcription format for automatic analyses by the CLAN program. We focused our analysis on the relationship between WMH load and composite scores representing the fluency factor (maze index) and the semantic factor (percent noun, verbs, and pronoun index) scores, both previously associated with cognitive impairment. Results: Preliminary data indicated that WMH load was negatively correlated with the semantic factor (r (55) = -.285, p =.017, one-tailed) for the Cat Rescue discourse measure. The semantic factor was negatively correlated with age (r (59) = -.347, p=.003, one-tailed). There was no significant relationship between the fluency factor for the Cat Rescue and WMH load. When evaluating the relationship between WMH load and overall cognition, we found that WMH load was negatively correlated with the total MoCA score (r (55) = -.259, p=.027, one-tailed) which was primarily driven by a strong relationship between WMH load and executive functioning (r (55) = -.248, p=.033, one-tailed), visuospatial (r (55) = -.341, p=.005, one-tailed), and attention (r (55) = -.276, p=.020, one-tailed) skills. Accounting for age, the relationship for both the MoCA (r (52) = -.255, p=.030, one-tailed) and semantic factor (r (52) = -.242, p=.038, one-tailed) remained significant with WMH load. Discussion: Higher WMH load was associated with worse performance on the MoCA and less semantic content in spoken discourse measured by the semantic factor in older healthy adults. In light of corroborating research indicating an association between WMH load in the brain and greater risk for cognitive decline and dementia, the current study provides evidence that WMH load may predict language changes in normal aging and age-related mild cognitive impairment.

Topic Areas: Language Production; Control, Selection, and Executive Processes

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Resting-state EEG signal complexity correlates with quality of narrative discourse in healthy older adults

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Introduction: Analysis of the non-linear complexity of electroencephalographic signals acquired during rest (rsEEG) can provide useful information concerning abnormalities in cortical and subcortical dynamics in the working brain. rsEEG complexity metrics have proven potent as biomarkers of symptom severity in multiple clinical models including mild cognitive impairment, Alzheimer's disease, Parkinson's disease, schizophrenia and depression. Acquiring rsEEG data is relatively inexpensive (compared to techniques such as MRI, PET and MEG) and is therefore may be a viable option for measuring brain health. The current study examines the relationship between rsEEG signal complexity (i.e. Lempel-Ziv complexity) and language production (i.e. quality of self-generated narrative discourse) in a sample of healthy older adults. Methods: As a part of the Aging Brain Cohort testing battery at the UofSC, a total of 47 healthy older adult participants produced narrative discourse and completed resting-state EEG testing. Narrative discourse was obtained using AphasiaBank's Cat Rescue picture description task, which requires participants to generate a story about a visual scene, complete with beginning, middle and end. Discourse samples were transcribed and coded using the CHAT transcription guidelines and linguistic variables were extracted using the CLAN program. Our primary language measures were the fluency factor (maze index) and the semantic factor (percent noun, verbs, and pronoun index). Eyes-open EEG data (3 minutes) was acquired using a 128-channel actiCAP EEG cap and a Brain Vision ActiChamp EEG plus system housed in an electronically shielded, custom-wired TeleAcoustic sound-proof booth. Following artifact removal using the Harvard-based HAPPE pipeline, Lempel-Ziv complexity (LZC) was calculated using the formula described by Lempel-Ziv (1976). Specifically, the EEG signal recorded from each electrode was transformed into a binary sequence using its median value as a threshold after which complexity was calculated by dividing the number of observed distinct patterns by the maximum complexity of the observed sequence. For each participant, whole-brain rsEEG complexity was calculated by averaging this measure across all electrodes. Results: In order to test the relationship between rsEEG signal complexity and discourse variables, we computed Pearson correlations between our measure of Lempel-Ziv complexity and two discourse measures (fluency & semantic factors). We found a positive correlation between rsEEG-based Lempel-Ziv complexity and individual semantic factor scores, $r(46) = 0.36$, $p = 0.006$, one-tailed, and a non-significant trend in the same direction for the fluency factor, $r(46) = 0.16$, $p = 0.13$, one-tailed. Discussion: The current study demonstrates that complexity of rsEEG signals is associated with the quality of narrative discourse production (semantic but not fluency factor) in a population of healthy older adults. Decreased rsEEG complexity in individuals with lower semantic factor scores may reflect abnormal interactions between disparate information sources involved in discourse generation. Reductions in rsEEG complexity may be due to a number of factors including neuronal death or partial deactivation of, or alterations in neuronal synchronization of language related networks. Future studies should explore the basis of rsEEG complexity variability as well as its potential utility as a biomarker of impaired language function throughout life.

Topic Areas: Language Production; Meaning: Discourse and Pragmatics

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Fight, Flight or Freeze? Emotional Stimuli and Word Retrieval in Aging Adults

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Introduction: Emotional stimuli have been shown to interfere with language production in neurotypical adults (Burbridge et al., 2005; White et al., 2016). One study by our group showed that the emotion-interference effect on word retrieval was greater for older than younger adults on an object picture naming task (Schwen Blacket et al., 2017). Stimulus type and task characteristics may also interact with effects of emotion on word retrieval (Okon Singer et al., 2013). The current study examined the robustness of this age-modulated effect of emotion on word retrieval by using four naming tasks that varied by stimulus type and word class in a new sample of younger and older adults. Methods: Twenty-one younger and 19 older adults participated in tasks presenting positive, negative, and neutral stimuli, taken from the International Affective Picture System (Lang et al., 2008) and Affective Norms for Emotional Words database (Bradley & Lang, 1999). Tasks included object picture-naming (60 items), action picture-naming (60 items), category-member generation (39 items), and verb generation (60 items). The three valence sets within each task had equal numbers of items and were balanced for word frequency, concreteness, imageability, age of acquisition, visual complexity (picture-naming tasks), and number of phonemes, syllables, and living vs. nonliving items. Task, valence block, and item-order were randomized across participants. Accuracy and reaction time (RT) were measured for each trial. Generalized logistic and linear mixed-effects models were used to evaluate differences in accuracy and RT between age groups and among tasks and valence. Results: All planned fixed effects were included in the final model (Age Group, Task, Valence, Task*Valence, and Task*Valence*Age Group). Participants were included as a random effect (intercept only). All fixed effects in the model were statistically significant ($ps < .05$). Across tasks, older adults scored slightly worse than younger adults (Older: $M = 96.6\%$, $SD = 2.0$, Younger: $M = 98.2\%$, $SD = 2.0$, $p = .011$) and demonstrated longer RTs (Older: $M = 1652$ ms, $SD = 284$, Younger: $M = 1467$ ms, $SD = 240$, $p = .031$). Younger and older adults responded poorest and slowest to negative trials compared to positive and neutral trials. Though accuracy on positive and neutral trials was not significantly different, RTs were significantly faster for neutral than positive trials for both age groups. This effect of emotion was greater for older adults than younger adults across all four tasks. This additional age-related slowing effect for emotional items was greatest for object picture-naming followed by category member generation, action picture-naming, and then verb generation. Conclusion: Emotional stimuli, and especially negative stimuli, appear to interfere with word retrieval performance, and this effect seems to be greater for older adults compared to younger adults. These findings replicate results from our previous study (Schwen Blackett et al., 2017), generalizing findings to three other naming tasks that included words in addition to pictures and action/verb naming in addition to object/noun naming, revealing the robustness of this age-modulated emotion effect on word retrieval. Theoretical hypotheses for these results will be discussed.

Topic Areas: Language Production; Meaning: Lexical Semantics

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Changes in the affective representation of words in emotional contexts

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Research debates whether people prefer positive or negative information, a.k.a. 'positivity bias' and 'negativity bias' (Kauschke et al., 2019). Studies so far primarily focused on faces and single words occurring in isolation. Here we examined words in context and asked whether the affective perception of a word could be changed by context. Behaviorally, only one study, to our knowledge, found negativity bias for words in context. Specifically, even though positive words such as "grandpa" are rated as being more positive than negative words like "burglar" based on affective norms, "The grandpa is lonely" is rated as equally negative as "The burglar is lonely" (Lüdtke & Jacobs, 2015). We used EEG to examine neural changes in the affective representation of a word before and after a certain emotionally loaded context. If negative bias holds, negative contexts should lead to more negative evaluation of the target words, regardless of the words' valence in isolation. Likewise, if positive bias holds, positive contexts should result in more positive evaluations of all target words. If neither holds, the very same word before and after the emotional contexts should show the same neural representations. Due to COVID-19 remote learning, only 21 undergraduates participated and 8 did not meet inclusion criteria. The remaining 13 (9 females, Mage = 19.5) were non-depressive (Beck Depression Index-II) with normal cognitive functioning (Mini-Mental State Examination). Stimuli included 320 three-sentence vignettes with target words (in square brackets) and contexts (in angle brackets) of different valence: 80 positive target words in positive contexts (The [pianist] had a new performance. Her skills were . The [pianist] practiced every day.), 80 positive target words in negative contexts (The [pianist] had a new performance. Her skills were . The [pianist] practiced every day.), 80 negative target words in positive contexts (The [dentist] often worked with children. They found him . The [dentist] cared about them.), and 80 negative target words in negative contexts (The [dentist] often worked with children. They found him . The [dentist] cared about them.). Target words were matched for length, frequency, and concreteness, and all low-arousing words, as our prior data suggested the difficulty to change affective perception towards high-arousing words. Participants did a valence judgment task while EEG was recorded. We computed and analyzed difference waves between the first and second occurrences of the target words. We found greater P2s (180-300 ms) for target words in negative contexts than in positive contexts, regardless of the word valence. Additionally, negative words elicited larger P2s than positive words, irrespective of context valence. We suggest that these reflect automatic attention towards negative content. A second finding is that target words in negative contexts showed larger LPPs (550-900 ms) than in positive contexts, regardless of the word valence. We argue that the attention underlying P2 was sustained through this time window. Altogether, these results indicate that the affective representation of a word can be changed after negative context, not positive context, supporting negativity bias. Data collection is ongoing to verify findings.

Topic Areas: Meaning: Discourse and Pragmatics; Meaning: Lexical Semantics

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Semantic networks across the lifespan: examining local network sensitivity and individual differences

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Introduction Recent evidence suggests that semantic networks undergo age-related changes (Cosgrove et al., 2021; Dubossarsky et al., 2017; Wulff et al., 2019). Previous research has shown that older adults' semantic networks had longer path lengths, less clustering, and higher modularity values compared to younger adults. These results indicate that younger adults have more efficient networks, less segregation of sub-communities, and greater flexibility for more efficient semantic processing (Cosgrove et al., 2021). Further, differences in retrieval processes can be quantified by measuring how connections between words in a semantic network break apart – the faster connections break apart the weaker the search processing. Such percolation analyses, have shown that older adults' semantic networks broke down faster compared to younger adults' networks, suggesting that younger adults' semantic networks were more robust. However, previous work has focused on group-based global network characteristics, with limited focus on local node characteristics or individual differences. Methods To address these limitations, we conducted two different analyses. First, we examined age-related differences in the local characteristics of each node (i.e., word) from previously examined semantic networks (N = 78 older, 78 younger adults). Specifically, we focused on node centrality measures (degree and clustering coefficient, which represent the number of connections a word has with other words in the network, and the extent to which neighbors of a node are neighbors of each other, respectively. In a separate study (N = 30 older, 30 younger), individual semantic networks were created from semantic relatedness judgements (Benedek et al., 2017). Global network properties including efficiency (path length), connectivity (clustering coefficient), and community structure (modularity) were correlated with individual performance on a verbal fluency task. Results We observed age-related differences in the local node characteristics of degree and clustering coefficient (all p's <.001), however there was no consistent pattern to these age-related differences. That is, some node degree values increased with age, while others decreased with age. Additionally, there were no significant age effects across individually-calculated network properties of average shortest path length, clustering coefficient, and modularity. These network characteristics also did not significantly correlate with individual differences in language production ability as measured by the total number of verbal fluency responses, number of category clusters, or number of switches between categories. Conclusion Consistent with prior research on global network measures between age groups, our analysis provides evidence of age-related differences in node-based measures, but with some nodes increasing and some decreasing. These findings reflect the sensitivity of processing within a semantic network, which can be influenced by changes in the local structural properties of certain nodes. Our individually calculated networks from semantic relatedness judgments did not show any age-related differences, or, relationships with language production measures. In contrast to our results, others have found individual differences in network structure similar to group findings (Wulff et al., 2018). These researchers found greater variance with increased age related to differences in life experiences among older adults which demonstrates the importance for future work to account for individual differences in the aging mental lexicon.

Topic Areas: Language Production; Meaning: Lexical Semantics

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Measuring Neural Grey Matter Correlations with Semantic Ability in Younger and Older Adults

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Older adults tend to have more difficulty in speech production compared to younger people (Tremblay and Deschamps, 2016; Burke & Shafto, 2007). Recent studies show that there is a relationship between language ability, age, and the brain (Kemmotsu et. al 2012). For example, age-related deficits in grey matter volume were related to lexical-semantic processing. However, studies of grey matter-behavior relationships have focused primarily on receptive language. What has been less studied is how age-related differences in neural structure relate to language production. For instance, younger adults are typically slower to name targets with high intercorrelational feature density (ICFD) because of the competition between targets and the related words (Rabovsky et al., 2016). ICFD is a measure of feature overlap among words or concepts that contributes to semantic selection demands. Since older adults have difficulty with semantic selection, we used sensitivity to ICFD as a proxy for semantic selection abilities and related this to cortical thickness and age. We hypothesized that age would be negatively associated with cortical thickness and that sensitivity to ICFD would be positively associated with cortical thickness in left-hemisphere regions such as the anterior temporal cortex, inferior frontal gyrus, and intra-parietal sulcus. 88 participants, ranging from ages 20 – 75, completed a picture-naming task during a 3T MRI scan. We collected functional and structural images. Of most relevance to the present analyses, T1 weighted anatomical images were collected using a magnetization-prepared rapid acquisition gradient-echo sequence (TR = 2300 ms; TE = 2.28 ms; field of view = 256 mm2; voxel size = 1 mm3). FreeSurfer was used to examine the relationship between cortical thickness and ICFD sensitivity as well as age. Data were preprocessed using the standard freesurfer pipeline (smoothing kernel = 10 mm). Results were cluster corrected for multiple comparisons using a Monte-Carlo simulation. Significance was set at $p < .05$. As expected, older age was negatively related with cortical thickness throughout the brain. ICFD was positively linked to cortical thickness of the left lingual gyrus (-27, -63, 4; cluster size = 545 mm2), right lingual gyrus (27, -57, 3; cluster size = 780 mm2) and right insula (37, -6, 2; cluster size = 522 mm2). There were no regions where ICFD was negatively related to cortical thickness. We found no significant clusters where the cortical thickness was related to reaction time or accuracy. As hypothesized, we found that Age was negatively related to cortical thickness. Moreover, sensitivity to ICFD was positively related to cortical thickness though in more bilateral regions than we originally anticipated (bilateral lingual gyri and the right insula). These results suggest that sensitivity to semantic competition are supported broadly, including regions outside traditional language hubs.

Topic Areas: Language Production; Meaning: Lexical Semantics

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The resting-state functional connectivity relates to aging and language production

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While many studies have examined age-related differences in resting-state functional connectivity, few studies have focused on the language network. This may be due in part, to the relative stability of many language functions across the lifespan. However it is unclear whether the characteristics of a resting-state language network are comparable in older and younger adults. In contrast to the language network, studies have shown that the connectivity within the multiple-demand (MD) network decreases with age. Yet, it is unclear if characteristics of the language and MD networks are associated with age-related differences in language production. The current study investigated the functional connectivity within resting-state language and MD networks, the connectivity between the two networks, and their relationship with age and language production. Participants across adulthood were tested (N = 169, 20-78 years, mean = 46 years). Participants completed a battery of neuropsychological tests to assess basic cognitive functions. Most relevant to this study, participants completed a story elicitation task using the picture book Frog Where Are you, where participants generated a story using the book as a guide. Discourse measures were calculated from the story to evaluate participants' language ability. Specifically, the Mean Length of Utterances (MLU) captures speech complexity by calculating the mean number of words in each utterance. The Moving Average Type/Token Ratio (MATTR) measures vocabulary by calculating the ratio of the number of different words divided by the total number of words in a moving window (N = 50). Functional resting-state images were collected while participants were instructed to relax in the scanner with their eyes open and to look at a fixation cross (duration = ~6 minutes). We focused on a pre-defined language network (Fedorenko et al., 2010) and a MD network (Fedorenko et al., 2013) using 4-mm radius sphere ROIs (8 for the language network, 20 for the MD network). We calculated the within-network connectivity for each network, the between network connectivity, and the mean network segregation ((within-between)/within) for each participant. To investigate the effect of age on network connectivity, we first conducted linear regressions on the network measures. We found that increased age was significantly associated with decreased within-network connectivity in the MD network, but there were no age-related differences in within-network connectivity in the language network, or in the between-network connectivity. These results suggest that the MD network was more sensitive to age effects while the language network connectivity was stable across adulthood. Additionally, increased age was associated with decreased network segregation, suggesting that resting-state networks become dedifferentiated with age. Preliminary results relating network characteristics to language ability showed that there was a significant interaction between age and within language network connectivity on MLU. Specifically, only in younger adults, but not in middle-aged or older adults, higher within language network connectivity was associated with higher MLU, indicating that stronger language network connectivity at rest in younger adults is related to the ability to produce more complex speech.

Topic Areas: Language Production; Methods

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The Aging Brain Cohort (ABC@UofSC) Repository: A multimodal database to study language and cognition across the lifespan

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Introduction: The Aging Brain Cohort at the University of South Carolina (ABC@UofSC) repository is a multimodal database derived from a planned, large-scale longitudinal and cross-sectional study of aging. In addition to genetic, behavioral/lifestyle and brain structure/function data, each participant completes a comprehensive cognitive battery which includes a wide range of language tasks not typically included in large scale studies of aging (e.g. multiple discourse tasks, sentence repetition, etc.). The ABC@UofSC database allows collaborating researchers to examine age-related changes in language processing, as well as their relationship to biological measures, with unprecedented ease and depth. Methods: Following collection of basic demographic data, participants are invited to complete a series of online questionnaires that assess medical history, mental and physical health, exercise and sleep patterns, quality of life, and various social factors. The first day of in-person testing involves collection of cognitive and sensory data, via the iPad version of the NIH Toolbox, as well as a series of language-related tasks that includes sentence repetition, phonological processing, self-paced reading, discourse (i.e. ‘Cat Rescue’, ‘Cookie Theft’, ‘Peer Conflict Resolution’ scenarios), vowel production, spatial release, words in noise and basic audiometric thresholds. The first day concludes with the collection of biological specimens (blood and buccal swabs) and resting-state electroencephlographic (EEG) data. The second day of testing involves collection of MRI data at the McCausland Center for Brain imaging. Specifically, brain structure (T1, T2, DTI) and brain function (resting state fMRI, task-based fMRI [word/picture familiarity judgment and listening English and non-English narratives] are measured using cutting-edge MRI sequences. Results: Currently the ABC@UofSC repository contains data from 65 healthy older adults (ages 60-80) as well as 100 additional individuals (ages 20-80) who were diagnosed with COVID-19. Sociodemographic data, along with data from all surveys, questionnaires and cognitive/language measures are stored in REDCap (Research Electronic Data Capture System). Both raw scores (e.g. ‘Cat Rescue’ transcripts) as well as derived scores (e.g. ‘Cat Rescue’ : duration, mean lexical units/utterance, type-token ratio, content words/minute, verbs/utterance, % word errors, total utterance errors, propositional density, total fillers, total false starts, total retracings, total repetitions, total pauses , fluency factor, semantic factor, CIU, etc.) are available upon request. EEG connectivity data is provided in the form of a 54-electrode connectivity matrix. Neuroimaging data is distributed in the form of custom MATLAB files which include ROI-based data for multiple imaging modalities (e.g. DTI-FA, DTI-MD, DTI connectivity, rsFMRI connectivity, Cat12-based VBM value, and publicly available free tools enable rapid testing of brain-behavior relationships (i.e. NiiStat). Currently, access to deidentified data is available to collaborating researchers and can be requested electronically via the REDCap link on the ABC@UofSC website (abc.sc.edu). Discussion: Healthy aging is associated with changes in language processing. The ABC@UofSC repository contains a wealth of data that will allow researchers to examine the relationship between age-related changes in language and a variety of other behavioral, cognitive and biological factors.

Topic Areas: Language Production; Speech Perception

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Cognitive control mediates age-related changes in flexible anticipatory processing during listening

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Effective listening comprehension not only requires processing local linguistic input, but also necessitates incorporating contextual cues available in the global communicative environment. Local sentence processing can be facilitated by pre-activation of likely upcoming linguistic input, or predictive processing. Recent evidence suggests that young adults can flexibly adapt local predictive processes based on cues provided by the global communicative environment, such as the reliability of specific speakers. Whether older comprehenders can also flexibly adapt to global contextual cues is currently unknown. Moreover, it is unclear whether the underlying mechanisms supporting local predictive processing differ from those supporting adaptation to global contextual cues. Critically, it is unclear whether these mechanisms change as a function of typical aging. In 40 young and 40 older adults, we examined the flexibility of prediction by presenting sentences from speakers whose utterances were typically more or less predictable (i.e., reliable speakers who produced expected words 80% of the time, versus unreliable speakers who produced expected words 20% of the time). For young listeners, global speaker reliability cues modulated neural effects of local predictability on the N400. In contrast, older adults, on average, did not show global modulation of local processing. Importantly, however, cognitive control (i.e., Stroop interference effects) mediated age-related reductions in sensitivity to the reliability of the speaker. Both young and older adults with high cognitive control showed greater N400 effects of predictability during sentences produced by a reliable speaker, suggesting that cognitive control is required to regulate the strength of top-down predictions based on global contextual information. Critically, cognitive control predicted sensitivity to global speaker-specific information but not local predictability cues, suggesting that predictive processing in local sentence contexts may be supported by separable neural mechanisms from adaptation of prediction as a function of global context. These results have important implications for interpreting age-related change in predictive processing, and for drawing more generalized conclusions regarding domain-general versus language-specific accounts of prediction.

Topic Areas: Meaning: Discourse and Pragmatics; Control, Selection, and Executive Processes

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Gamified Tip-of-the-Tongue Assessment in Aging

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Tip-of-the-tongue (ToT) is a common word-finding difficulty that worsens with age, serving as a potential warning sign of neurodegeneration. Most measures of word-finding difficulty focus only on single-word naming accuracy, which is not sensitive enough to assess ToT experienced by healthy older adults. To evaluate a potentially more sensitive ToT assessment, this study on young adults implemented three experiments that developed a word-picture interference paradigm not requiring a vocal response, while also evaluating gamified versions of the three experiments. In the word-picture interference paradigm, a target picture was accompanied by an audio word distractor that was either unrelated, phonologically-related, associatively-related, or categorically-related to the picture. Participants were instructed to indicate by button press whether the name of the picture ended in a particular phoneme varying by block. Experiment 1 (29 young healthy adults, age: 19.28 +/- 3.12) and Experiment 2 (33 young healthy adults, age: 23.21 +/- 5.69) successfully elicited the categorical slowing (word-picture interference) and phonological speeding (word-picture facilitation) at different optimal stimulus-onset-asynchronies between words and pictures. Experiment 3 (33 young healthy adults, age: 22.85 +/- 5.19) demonstrated that a key gamification feature (collecting coins for good performance) motivated higher speed at the expense of accuracy in the gamified versus experimental format of the task. In spite of speed-accuracy tradeoff, the gamified version of the experiment still demonstrated the expected categorical slowing and phonological speeding effects. In total, the three experiments established the optimal non-verbal paradigm and verified the validity of the gamification. With the upcoming fourth experiment, we will recruit 40 young (18-34 year-old), 40 young-old (60-74 year-old), and 40 old-old (75-89 year-old) healthy adults evaluate the word-picture interference and facilitation effects as potentially more sensitive measures of ToT, related to other neuropsychological test scores. With many older people being less willing or able to travel to labs for in-person experiments, remotely accessible cognitive assessments are needed for characterization of the precursors of cognitive impairment. In addition to improving our understanding of the ToT phenomenon, the results of this study demonstrate that gamification can enable more sensitive, convenient, and engaging assessment for word-finding difficulties, highly suitable for online experimentation, and possibly relevant to a range of other experimental paradigms of relevance to the study of cognitive aging.

Topic Areas: Methods; Language Production

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The efficiency of the Functional Networks in the Bilingual Ageing Brain

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Introduction: Life-long experience of using two or more languages has been shown to enhance cognitive control abilities in young (Bialystok et al., 2012; Costa et al., 2008) and elderly (Berroir et al.,2017; Luk et al., 2011; Dash et al., 2019) bilinguals. By frequently practicing the language control mechanism, bilinguals tend to be faster and more accurate in tasks of attention, working memory, and cognitive control. The bilingual advantage is also evident in the structural and functional differences in the regions related to bilingual language control. Thus, bilingualism can be considered to build a cognitive reserve that supports the maintenance of cognitive function, despite brain decline. The current study examines the effect of bilingualism on the resting-state functional connectivity (rsFC) for young and elderly bilinguals. Methods: 27 young bilinguals (YB; Mean age = 35.34 years, 12 F) and 28 elderly bilinguals (EB; Mean age = 69.7 years, 19 F) participated in the study. All participants were French speakers who spoke English as a second language (L2). Measures of bilingualism were assessed using the LEAPq (Marian et al., 2007) and objective language tasks (Dash et al., 2019). In addition, the cognitive reserve index questionnaire (Nucci et al., 2012) was also completed by the participants. The rsFC between individuals varying in age and measures of bilingualism were compared to explore the changes in functional connectivity using ROI to ROI analysis. Data were preprocessed and analyzed using the CONN toolbox with SPM12. Results: Brain-wide, YB showed stronger rsFC within network connectivity for the salience (ventral attention), visual, somatomotor, and frontoparietal control network compared to EB, consistent with the idea of a reduction in age-related functional connectivity. Our results indicate that the brain-behavioral relationship demonstrates a positive correlation between the strength of within-network rsFC and the behavioral effect of alerting, orienting, and executive control. Also, L2 proficiency and exposure – defined as a continuous variable – impacts brain plasticity by modulating the rsFC within the salience network only. Conclusion: Together, our findings highlight the age-related reduction in rsFC in EB when compared to YB. Furthermore, our results indicate that bilingual experience when other proxies of the cognitive reserve are controlled for modulates the functional connectivity within salience network, i.e., with increasing L2 proficiency and exposure, there is an increase in the strength of connectivity within salience network. Salience network – left frontal opercular areas – are related to establishing relevant stimuli in the environment and is typically associated with error processing. It is likely that with more L2 proficiency and usage, the bilingual brain tends to tap into salient cues in the environment to perform more efficiently. These findings shed new light on the importance of modeling bilingualism as a continuous variable rather than dichotomous.

Topic Areas: Multilingualism; Control, Selection, and Executive Processes

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Finding a new treatment option for speech perception in noise difficulties in the elderly: a TMS study

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Older adults frequently report having difficulties following conversations in noisy environments. Available therapies are not efficient to reduce these difficulties, which are associated with reduced social participation. The etiology of these difficulties is unclear but appears to be independent from peripheral hearing [1]. A recent functional MRI study from our group [2] found that the activation patterns within the ‘speech network’ are different in young and older adults, including in the superior temporal sulcus (STS), which is implicated in phonological processing, and the ventral premotor cortex (PMv), which contains articulatory representations of speech sounds. Optimizing the functioning of these regions could alleviate speech perception in noise (SPiN) difficulties in the aging population. Transcranial magnetic stimulation (TMS) is a powerful tool to induce plasticity within specific brain regions. However, the potential of this method to reduce SPiN difficulties in adults is unknown. OBJECTIVE. The aim of this study was to determine if SPiN can be improved in young and older adults by excitatory TMS over the STS and the PMv. We expected that aging would be associated with lower SPiN performance and that all participants would show performance improvement after TMS. We also expected stronger TMS-induced benefits in younger adults, as their brain is presumed more plastic. METHOD. 34 healthy right-handed adults aged 32 to 79 years were recruited. Anatomical brain images (1 mm3, Philips Achieva 3T) were acquired for each participant. The targets for TMS (left STS, left PMv) were localized based on participants’ anatomy and previous studies [3-4]. The vertex was used for the sham condition. An excitatory intermittent theta-burst (iTBS) protocol [5] was used. After each stimulation, a sublexical SPiN task was run, in which participants had to indicate if pairs of syllables were identical or different. Cognition (MoCA; [6]) and hearing (tonal audiometry) were also evaluated. Multiple regressions were used to assess age effects on baseline (sham) performance (accuracy and reaction time (RT)). Cognitive level and hearing were included as covariates. Linear mixed models (LMM) were used to assess the effects of age, target and baseline performance on TMS-induced improvement scores (experimental – sham). RESULTS. Aging was associated with lower accuracy in the baseline condition ($\beta = -0.37$, $p < 0.001$). LMM analyses revealed a stronger gain in accuracy after PMv compared to pSTS stimulation ($F(1, 25) = 7.19$, $p = 0.013$). A lower baseline performance was associated with stronger improvement on accuracy ($F(1, 25) = 6.16$, $p = 0.020$) and RT ($F(1, 24) = 23.70$, $p < 0.001$). CONCLUSION. TMS can successfully improve SPiN performance. A better understanding of the etiology of SPiN decline and the factors that influence TMS responses will guide the development of new strategies, based on brain stimulation, to prevent these persistent difficulties in the aging population.
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Topic Areas: Speech Perception; Language Therapy

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The relationship between memory and sentence processing in the aging brain

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Introduction: Healthy aging is associated with subtle declines in sentence processing that have been linked to structural and functional properties of the brain. Age is also related to a decline in memory abilities that contribute to sentence processing, providing a useful model to study the relationship between memory, sentence processing, and the brain. Here, we examined the relationship between grey matter volume (GMV) and white matter connectivity measured using diffusion tensor imaging (DTI) with sentence processing, working memory (WM), auditory-verbal memory (AVM), and phonological short-term memory (PSTM) in a group of healthy older adults. Methods: Sixty participants (40 Female, 20 Male) between the ages of 60 and 80 ($M = 66.78$, $SD = 6.98$) were recruited as part of the Aging Brain Cohort Study at the University of South Carolina. Participants completed a sentence repetition task with 30 sentences, and three memory tasks from the National Institutes of Health (NIH) cognitive battery. In the WM task, animal and food words and pictures are shown to participants, who must then repeat back the items in order from smallest to largest. In the AVM task, a list of fifteen unrelated words is read aloud to participants, who must then repeat as many words back as they can. In the PSTM test, participants must repeat pronounceable nonwords of increasing length. Structural MRI scans were collected. Voxel-based morphometry (VBM) was used to determine where GMV was associated with memory and sentence processing within a bilateral mask consisting of inferior frontal gyrus pars opercularis and triangularis (IFGoper, IFGtri), supramarginal and angular gyri (SMG, AG), and posterior middle and superior temporal gyri (pMTG, pSTG). Additionally, a connectivity matrix of fiber counts between areas within this network was created for each participant from DTI scans. Structural correlates of sentence and memory tasks were examined first. Next, sentence repetition, controlling for memory, was analyzed by adding all memory tasks as nuisance regressors. All analyses controlled for age and family-wise error (FWE) error corrected ($p < .05$) unless otherwise noted. Results: All 3 memory tasks were correlated with sentence repetition ($p < .05$). VBM revealed clusters in right AG, pMTG, and bilateral IFGtri that were associated with worse WM performance ($p < .001$, uncorrected). A cluster in the right AG was associated with AVM ($p < .001$, uncorrected). Sentence repetition was associated with clusters in the left SMG and bilateral IFGtri (FWE, $p < .05$). When controlling for memory tasks, a cluster in the left SMG was associated with sentence repetition performance (FWE, $p < .05$). DTI revealed greater connectivity between the left SMG and pMTG was related to better sentence repetition, even after controlling for memory tasks. Conclusions: WM, AVM, and PSTM abilities are associated with sentence processing in older adults. VBM and DTI revealed that structural properties of the left SMG are related to sentence repetition independently of memory. We interpret this as reflecting the high sensory-motor integration demands of sentence processing compared to the other tasks, in which the left SMG plays a critical role.

Topic Areas: Syntax; Control, Selection, and Executive Processes

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Neuroanatomical correlates of canonical and noncanonical sentence processing in the aging brain

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Introduction: Healthy aging is associated with subtle declines in language abilities that have been linked to structural and functional changes in the brain. Age disproportionately impacts the processing of syntactically complex sentences, providing a useful model to study the neuroanatomical structures associated with processing different syntactic constructions. Here, we examined the relationship between grey matter volume (GMV) and resting-state fMRI (rsfMRI) with sentence processing performance of four different syntactic structures in healthy older adults. Methods: Sixty participants (40 Female, 20 Male) between the ages of 60 and 80 (M = 66.78, SD = 6.98) were recruited as part of the Aging Brain Cohort (ABC@UofSC). Participants completed a sentence repetition task containing 30 recorded sentences (5 active, 5 passive, 10 canonical [object-subject or subject-subject], and 10 non-canonical [object-object or subject-object]). Sentences were presented one-by-one and participants were asked to repeat each sentence. Accuracy was measured as percent of words correctly repeated in order. Sentences were matched for number of syllables, words, word frequency, and semantic density. Subsequently, structural and rsfMRI scans were collected. We computed correlations between performance on each sentence type and GMV within language regions known to be associated with sentence processing including the inferior frontal gyrus pars opercularis and triangularis (IFGoper, IFGtri), supramarginal and angular gyri (SMG, AG), and posterior middle and superior temporal gyri (pMTG, pSTG). The relationship between rsfMRI and sentence type was analyzed using multivariate support vector regression (SVR) and proportional amplitude of low frequency fluctuations (pALFF) within all 110 grey matter regions of the Johns Hopkins University atlas. Analyses controlled for age and were conducted for each sentence type individually, as well as directly comparing active vs. passive and canonical vs. noncanonical using nuisance regression. VBM clusters were FWE corrected $p < .05$, and SVR used permutation correction (1000 permutations, $p < .05$). Results: Participants were significantly less accurate at repeating active compared to passive sentences, $p = .001$. Canonical and noncanonical sentence repetition accuracies were not significantly different, $p = .5$. Poorer performance on active sentences was associated with reduced GMV in right SMG and IFGtri. Repetition accuracy for active sentences was correlated with greater pALFF in a mostly right-lateralized medial-temporal and parietal areas (e.g., pMTG, AG, entorhinal cortex, and parahippocampal gyrus). Results remained significant after controlling for passive sentences, and no GMV or SVR results were predictive of passive sentences individually. Repetition accuracy for canonical and noncanonical sentences was associated with increased GMV in left SMG and bilateral IFGtri. Analysis of pALFF revealed partially dissociable areas associated with accurate repetition of canonical (right-lateralized fronto-temporal regions, e.g., insula, temporal pole) and noncanonical (bilateral posterior temporoparietal areas, e.g., AG, pSTG) sentences. Conclusions: Overall, our results suggest that brain areas associated with processing sentences with different syntactic structures are partially dissociable. Additionally, both the GMV and rsfMRI results provide converging evidence that structural and functional properties of right hemisphere areas may be especially predictive of sentence processing decline in healthy older adults.

Topic Areas: Syntax; Language Production

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Personal discourse as an index for mental health and neurological impact of COVID-19

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Introduction: Emerging evidence suggests that SARS-CoV-2 (COVID-19) can be the cause of long-term neurological impairment, even with disparate levels of infection severity. Neurological symptoms that include; fatigue, impaired cognition, increased anxiety, depression, and loss of taste/smell. Stress and prolonged anxiety can result in acute and chronic changes in neurochemical systems and brain regions (hippocampus, amygdala, and medial prefrontal cortex). Here, we evaluate the utility of self-generated narrative discourse (personal COVID-19 stories) as a potential predictor of persistent neurological and mental health effects of COVID-19 as indexed by questionnaires, assessments, and MRI brain markers. Methods: 110 recovered individuals (ages 20-71) who experienced varying COVID-19 severity completed questionnaires, behavioral, and neuroimaging tasks. Self-generated narrative discourse samples detailing individual COVID-19 experiences were recorded and transcribed using Microsoft 365 software by trained assistants for accuracy. Using the Text Mining package tidytext (R-Studio), we analyzed the frequency of positive/negative words and categories of sentiment as defined in the NRC Word-Emotion Association Lexicon. Emotional valence, sentiment, mental health, viral severity, and brain measures of white matter hyperintensities (WMH) measured by Fazekas scale and gray matter volumes (GMV) measured using Cat12 were evaluated with one-tailed Pearson correlations. Results: Overall emotionality of COVID-19 stories was negatively correlated with mental health and well-being. Negative sentiment was associated with higher anxiety ($r(109)=-.203$, $p = .017$), depression ($r(109)=-.205$, $p = .016$), sleep disturbance ($r(109)=-.211$, $p = .014$,), and PTSD severity ($r(109)=-.264$, $p = .003$). More negative content in the COVID-19 story was also correlated with worse MoCA performance ($r(109)=.232$, $p = .007$) and MoCA fluency ($r(109)=.197$, $p = .02$). Accounting for age, the relationship between the overall emotional valence and MoCA scores remained significant ($r(109)=.260$, $p =.003$). Additionally, we evaluated the relationship between neural integrity (GMV and WMH) and emotion scores. Results indicate higher GMV in the left hippocampus with overall negative emotional content ($r(105)=-.184$, $p =.03$). GMV in the left hippocampus and left amygdala correlated with sentiment of fear ($r(105)=-.172$, $p =.03$), trust with the right and left hippocampus ($r(105)=-.190$, $p =.02$). Higher anxiety was correlated with higher GMV in the left hippocampus ($r(105)=.228$, $p =.01$). Periventricular WMHs were correlated with fear($r(97)=.183$, $p =.03$), sadness ($r(97)=.173$, $p =.04$), and trust ($r(97)=.192$, $p =.03$), but not joy ($r(97)=.043$, $p =.329$). Deep WMHs were correlated with depression ($r(97)=-.171$, $p =.04$). Discussion: Self-generated discourse about prior stressful events can be used as an index of mental health and underlying neurological change in areas known to be related to memory and emotion including the hippocampus and amygdala. Further studies are needed to determine if these effects are a direct result of the COVID-19 virus itself or related to other, co-occurring factors. Analysis of discourse content could help identify individuals facing long-term neurological impacts and most in need of support/intervention.

Topic Areas: Meaning: Discourse and Pragmatics; Language Production

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Where in the brain is “pragmatics”? The case of verbal metaphors in aphasia

Laura Pissani[1], Caitlyn Antal[1], Kyan Salehi[1], Alexa Ray Falcone[1], Roberto G. de Almeida[1]; [1]Concordia University

INTRODUCTION The comprehension of sentences such as “The professor devoured the paper” requires generating inferences on the relation between the subject (professor) and the object (paper) beyond what the verb (devour) means literally. Thus, metaphor comprehension might rely on an early parsing that is based on linguistic (viz., syntactic-semantic) predicate-argument relations, which are then further interpreted through non-linguistic (viz., pragmatic) inferential processes. Much research has focused on examining the contribution of the right and left hemispheres in linguistic and non-linguistic aspects of language comprehension. Early studies have reported that patients with right hemisphere damage (RHD) have difficulties when drawing inferences from sentences or discourse (Beeman, 1993; Brownell et al., 1986), suggesting that the RH is crucial for processing pragmatic information, including metaphors (Winner & Gardner, 1977) and connotative aspects of lexical meaning (Brownell et al., 1984). However, more recent studies have reported conflicting results, wherein patients with either left hemisphere damage (LHD; e.g., Cieślicka, Rataj, & Jaworska, 2011) or RHD (Ianni et al., 2014) show difficulties with metaphor comprehension when compared to healthy controls. Our primary goal was to investigate how RHD and LHD patients, with different etiologies, interpreted sentences containing verbal metaphors in contrast with other sentences. METHOD Participants included 4 fluent [FL], 5 non-fluent [NF], 3 mixed but predominantly non-fluent [MN], 2 with mixed aphasia [MX], and 41 healthy controls. In each trial, participants were aurally presented with a sentence, which was immediately followed by two pictures on a computer screen. Their task was to choose the picture that best represented the sentence they heard. We contrasted four different types of sentences: (a) metaphorical (The professor devoured the paper), (b) literal (The professor read the paper), (c) indeterminate (The professor began the paper), and (d) determinate (The professor marked the paper). Given that indeterminate sentences are also said to rely on pragmatic enrichment (de Almeida, 2018), they were treated as pragmatic controls for metaphorical sentences. Only one of the pictures was the correct choice for the metaphorical and literal sentences, whereas the second picture was the correct choice for the indeterminate and determinate sentences. RESULTS Repeated-measures ANOVAs showed that, when compared to healthy controls, FL and MX had significantly more difficulty choosing the correct picture when presented with metaphorical sentences. Moreover, we found an effect of hemisphere, whereby individuals with LHD performed significantly worse than controls only with metaphorical sentences. Interestingly, the opposite pattern was found for individuals with RHD. Namely, individuals with RHD had significantly more difficulty choosing the correct picture in comparison to controls, only when presented with indeterminate sentences. Case-series analyses will be presented. DISCUSSION Our analyses suggest that the comprehension of metaphorical sentences may predominantly rely on the recruitment of semantic and pragmatic processes in the LH. We also found that the comprehension of indeterminate sentences —which arguably also rely on pragmatic enrichment—was significantly more impaired in individuals with RHD. Given this dissociation pattern, our results suggest that the interpretation of metaphorical and indeterminate sentences may rely on different underlying pragmatic processes.

Topic Areas: Meaning: Discourse and Pragmatics; Disorders: Acquired

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Voystick: a vocal joystick for vowel production training

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Auditory and somatosensory feedback help guide speech movements, but learning novel production targets, such as non-native vowels, can still be a challenge for adult speakers. The current study investigates speakers' ability to use visual feedback to refine vocal movements during vowel production. Sixteen participants took part in a single-session speech motor learning paradigm in which their spoken acoustics were mapped to a real-time cursor display. Participants used this "voice joystick" (Voystick) to move the cursor to visual targets defined in formant frequency (F1-F2) space. Two targets corresponded to native English vowels (/ɛ/, /ow/), with target formants defined by speaker-specific baseline productions; two targets were novel vowels (/ø/, /ɯ/), defined as linear combinations of formants from the baseline productions. Participants completed 45 5-second trials for each target in a pseudorandom order. To achieve a "hit" for a given trial, they had to vocalize while maintaining vowel formants within 50 mels of the target for at least 300 ms. The experiment instructions encouraged participants to vary their vowels continuously, demonstrating a gradual continuum between /i/ and /u/, and specified that changes to voice pitch would not affect the cursor movement. Formant tracks were visually inspected, and mistracked trials or segments of trials were excluded from further analysis. Over the course of the experiment, speakers showed evidence of motor learning, achieving vowel target "hits" more often and more quickly, and spending proportionally more time in the vicinity of the targets, as defined by the average distance over the course of the trial (all $p < 0.005$). Native and novel vowels did not differ in the percentage of targets reached or in the average time to target, but native vowels achieved a closer average distance to the target by the end of the experiment than novel vowels ($p = 0.002$). This work establishes the capacity of the Voystick system to promote speech motor learning, and has the potential to investigate the formation of vocal motor programs in the absence of auditory feedback.

Topic Areas: Speech Motor Control; Multisensory or Sensorimotor Integration

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Sensorimotor Adaptation in Bilingual Speech

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Sensorimotor adaptation in speech is typically studied by altering the sound of the voice as vowel sounds are produced. After a period of baseline production, the formant structure of the vowel sound is altered in real-time so that participants hear a different vowel from the one they intended to produce. Over hundreds of trials, adaptation is observed; participants alter their formant productions to offset the induced acoustical error. We recently demonstrated that sensorimotor adaptation like this can also be observed during the production of complex sentences (Lametti et al. 2018). Here we expand on this idea to examine the relationship between language and sensorimotor control in speech. In a group of L1 French / L2 English bilinguals, we use the rich linguistic environment afforded by sentence production to test whether sensorimotor adaptation acquired during French sentence production could be applied to vowel production in English, and vice versa. Participants read matched French and English sentences into a microphone as they appeared on a computer screen and heard themselves in real-time through headphones. After a period of baseline production, the first and second formant frequency of all produced vowels was altered by -49.5 mel and +49.5 mel (respectively) to induce sensorimotor adaptation. Before and after adaptation, a transfer test involving the production of isolated words with noise masking assessed formant production in the complete absence of auditory feedback. The transfer test consisted of randomized productions of eight English words and eight French words with comparable vowel sounds (e.g., "pat" and « patte »). Twenty adult participants were tested (10 male, 10 female), all of whom were L1 speakers of Quebec French and moderate/high proficiency speakers of English. Subjects were tested in two sessions, one week apart. In one session, they experienced sensorimotor adaptation during English sentence production, and the extent of transfer to both English and French words was assessed; in the second session, they experienced sensorimotor adaptation during French sentence production, and the extent of transfer to English and French words was assessed. Session language order was balanced across the 20 participants. Speech adaptation was indexed by the degree to which changes in formant production opposed the formant alteration. Participants offset 30-35% of the induced acoustical error in both languages. Compensatory speech patterns learned in the context of French sentence production were readily applied to the production of both French and English words. Compensation acquired during English sentence production similarly showed robust transfer to word production in both English and French. These results suggest that, in speakers of more than one language, newly acquired sensorimotor transformations in speech may not be language specific, but rather are applied to vowels across language contexts.

Topic Areas: Speech Motor Control; Multilingualism

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Perception of ASL fingerspelling via point-light displays

Carly Leannah[1], Athena S. Willis[1], Lorna C. Quandt[1]; [1]Gallaudet University

While there is research on how sign language and fingerspelling is generally perceived among signers with different language experiences, perception of fingerspelling in varying visual environments is not well understood. Given that signed language users communicate in a wide array of sub-optimal environments, such as in the dark or from a distance, it is important to know more about how signers read fingerspelling in such circumstances. Signed languages such as American Sign Language (ASL) rely on visuospatial information that combines linguistic features such as hand and bodily movements, facial expressions, and fingerspelling. Linguistic information in ASL is conveyed with movement and spatial patterning, which leads to the possibility of studying the perception of both movement and language by using dynamic Point Light Display (PLD) stimuli to represent the joint movements of sign language. The stimuli used in this study consisted of fingerspelled location names. The location names were either real (e.g., KUWAIT) or made-up (e.g., CLARTAND), and the PLDs were made up of either high or low numbers of markers. We present results from a behavioral study in which deaf, hard-of-hearing, and hearing ASL users (total n = 292) watched the 28 PLD stimulus videos (half real, half made-up; half high # markers, half low # markers). After viewing each video, participants typed the fingerspelled word that was displayed in the video and self-rated on how confident they were about their answer. We predicted that when ASL fingerspelled letter strings are seen in a suboptimal visual environment, language experience in ASL will be positively correlated with accuracy and self-rated confidence scores. We also predicted that real location names would be more readily understood than made-up names. Our preliminary findings show that participants were more confident with their responses when the fingerspelled words were real than when they were fake ($f(1,269) = 451.43$, $p < .001$, $\eta 2 = 0.55$). Participants were also more confident with typing their responses when the fingerspelled videos had the high number of markers than the lower number ($F(1,269) = 101.364$, $p < .001$, $\eta 2 = 0.019$). We will also present analyses of response accuracy and effects of language experience. Studying the relationship between language experience with PLD fingerspelling perception will allow us to explore how hearing status, varying ASL fluency levels, age of language acquisition, and other language experiences affect the core abilities of understanding fingerspelling in varying visual environments.

Topic Areas: Signed Language and Gesture; Multilingualism

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Sensorimotor reactivity in passive and active discrimination of ASL: A preliminary analysis of EEG mu rhythm evidence.

Edith Dong[1]; [1]Gallaudet University

Speech perception has been routinely investigated through analysis of the mu rhythm as recorded by electro/magneto-encephalography. The mu rhythm has repeatedly been shown to be sensitive to the sensorimotor and cognitive demands associated with speech perception tasks from simple (passive perception) to more complex (discrimination and discrimination in noise). Primarily, these studies have utilized auditory and/or visual speech signals while varying task difficulty to assess mu rhythm reactivity over the time course of the stimulus to differentiate between automatic sensory-to-motor transformations and general cognitive demands. Evidence exists supporting both these interpretations, with a strong focus on spoken language, auditory-to-motor transformations, and general cognitive demands such as working memory and attention. Limited evidence exists investigating similar processes in visual/manual languages such as American Sign Language (ASL). ASL utilizes single or two handed signs that are characterized by hand-shape, movement, and position, with additional modification and meaning cues carried by facial expression. The goal of this preliminary study was to investigate mu rhythm reactivity in ASL perception and discrimination tasks, differentiating activation between automatic visuo-motor transformations and cognitive demands. Participants watched a control condition (modulated/kaleidoscope signs), and 3 test conditions (one handed left/one handed right/two handed). Each test condition included 80 trials and was run twice, once passively, once with a required response (same/different). EEG data were collected with a 32 channel Emotiv Flex system and analyzed with MATLAB and EEGLab. Mu rhythm results on pilot data suggest that mu-alpha and beta suppression is present in passive and active discrimination tasks, though stronger in discrimination tasks. In addition, one and two handed signs revealed different patterns of mu suppression across the left and right sensorimotor areas, suggesting visuo-motor mapping accurately reflects motor demands associated with self-reproduction of the signal. Though preliminary, this study suggests that perception of ASL similarly recruits and modulates the sensorimotor mu rhythm via changes to task demand while reflecting sensory-to-motor transformation across both the left and right hemispheres.

Topic Areas: Multisensory or Sensorimotor Integration; Signed Language and Gesture

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Real-Time Speech Production Envelope Reconstruction with MEG

Debadatta Dash[1], Paul Ferrari[1,2], Jun Wang[1]; [1]University of Texas at Austin, [2]Helen DeVos Children's Hospital, Spectrum Health

Neural speech decoding retrieves speech information directly from the brain signals. This approach holds promise for providing better communication assistance to patients with locked-in syndrome (e.g. due to amyotrophic lateral sclerosis, ALS). However, speech decoding research using non-invasive neural signals has been limited to discrete classifications of only a few speech units (e.g., words/syllables/phrases). Considerable work remains to achieve the ultimate goal of decoding any internalized speech sounds. One stepping stone towards this goal would be to reconstruct the overt speech envelope in real-time from neural activity. Numerous studies have shown the possibility of tracking the speech envelope during speech perception but this has not been demonstrated for speech production. Here, we attempted to reconstruct the speech production envelope by decoding the temporal information of speech processing directly from neuromagnetic signals using Magnetoencephalography (MEG). MEG has been proven effective in tracking and decoding speech information in real-time due to its excellent temporal resolution. We collected neuromagnetic activity from 7 subjects speaking 5 different cued phrases (~100 trials per phrase) and from 7 different subjects speaking 'yes' or 'no' randomly (~80 trials per word) without any cue. We performed a single-trial regression analysis of the spoken speech envelope from the preprocessed gradiometer signals in real-time with 4 kHz sampling frequency using a bidirectional long-short-term-memory recurrent neural network based deep learning approach. We used wideband (0.3 - 250 Hz) neuromagnetic activity for envelope synthesis and compared it to the performance obtained using only low frequency oscillations (delta: 0.3 - 4 Hz) and delta + theta (0.3 - 8 Hz). For full spectrum decoding we successfully reconstructed the speech envelope with correlation scores of 0.82 and 0.72 for yes/no words and phrases, respectively. In the case of spoken words (yes, no), we found that the average correlation score obtained was significantly higher ($p < 0.05$, 1-tail paired t-test) when brainwaves with all frequencies were used compared to using delta or delta + theta only. This may indicate the importance of high frequency brain activity in characterizing dynamic information processing during speech production. However, it is also possible that the temporal characteristics of low frequency neural oscillations were not well represented due to the short analysis time windows (~ 0.3s). Indeed, for decoding phrase data with longer periods (~2 s), there were no significant differences between the low frequency and wideband pipelines. We conclude that using neural signals with all frequencies might be more efficacious for single-trial analysis of speech production envelope synthesis. In summary, this study demonstrates that it is possible to reconstruct the speech production envelope from the MEG signals in real-time providing the foundation for direct speech synthesis from non-invasive neural signals.

Topic Areas: Computational Approaches; Speech Motor Control

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An increased influence of biological motion on speech perception in those with superior kinesthetic working memory

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Because spontaneously produced gestures often unfold in tandem with prosodic fluctuations in speech, gestures can influence discourse processing by inducing expectations about the precise timing of upcoming speech. Biological motion that correlates with sonic energy peaks can help optimize how the brain samples auditory information by modulating phase relationships between ongoing neural oscillations and the speech signal. Cross-modal coordination of this sort would be indexed by an increase in the phase alignment of low frequency activity (~3-7Hz) to speech that is preceded by the onset of a gesture. Here we investigate the role of gestures in tuning expectations about speech onset and whether kinesthetic working memory (KWM), that is, memory for body movements, supports these processes. KWM was assessed in 25 healthy adults using a movement span task that quantified their ability to memorize and reproduce a series of meaningless body postures. In a subsequent study, EEG was recorded as those participants viewed multimodal discourse clips with either congruent or incongruent speech and gestures. Cluster-based permutation tests revealed a main effect of speech-gesture congruency on ERPs to content words in the speech ($p<0.001$). Words in incongruent discourse clips elicited more negative ERPs than those accompanied by congruent gestures beginning approximately 350ms after onset. This N400 effect confirms the facilitatory role of gestures in semantic retrieval. To explore the role of KWM in phase resetting of theta band activity to speech, we measured the intertrial phase coherence of EEG elicited during congruent versus incongruent discourse clips. Analysis across all participants indicated phase alignment in low frequency activity was more pronounced in congruent relative to incongruent speech-gesture pairings. Cluster-based permutation tests on the interaction of this congruency effect and KWM revealed a relationship between KWM scores and more positive intertrial phase coherence in the theta band (3-5Hz) from 80-150ms after speech onset in congruent relative to incongruent videos ($p<0.05$). Results suggest participants with greater KWM capacity were more sensitive to how visual biological motion cues in gesture influenced theta resetting to the speech signal. Overall, these data support a role for KWM in multimodal discourse processing by promoting sensitivity to dynamic features of biological motion in a way that affords efficient auditory processing of the speech signal.

Topic Areas: Meaning: Discourse and Pragmatics; Multisensory or Sensorimotor Integration

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Orofacial somatosensory inputs change the auditory categorization in perceptual adaptation training

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Orofacial somatosensory system intervenes in the perception of speech sounds. Recent study also showed that somatosensory input during speech motor learning can play an important role in the change of speech perception. However, it is still unclear that repeated exposure of somatosensory stimulation during speech perception can also induce an adaptive change of speech representation. This study examined whether speech perception system can be modified by perceptual training involving repeated exposure of orofacial somatosensory stimulation. We focused on the perceptual threshold between /e/ and /a/, and examined whether this perceptual threshold is changed between prior to and following the perceptual adaptation training. We tested 15 native speakers of French. The experiment consisted of three sessions. The first session was the test to measure baseline level of perceptual threshold. The second session was the perceptual adaptation training with somatosensory stimulation associated with facial skin deformation. The third session was the perceptual test again to measure aftereffects of the training. In the first and the third session, we applied an adaptive method based on the maximum-likelihood procedure to detect perceptual threshold by small number of trials. Seventeen trials are used to determine a perceptual threshold. We repeated four times of this test in one session. In the second session, we applied method of constant stimuli using 10 continuum between /e/ and /a/ in order to be exposed all stimulus variants equal number of times. We presented each stimulus in a pseudo-random order for 50 times. In this session, we also applied somatosensory stimulation when the stimulus sound was presented. Given that the target vowels (/e/ and /a/) are characterized by articulatory vertical movements, facial skin deformation was applied in the upward direction. In all sessions, subjects' task was to identify whether the presented sound was /e/ or /a/ by pressing a key on a keyboard as quickly as possible. The stimuli were presented through headphones at a comfortable volume level. Perceptual thresholds between /e/ and /a/ were identified as the 50% point of the psychometric function estimated by fitting a logistic function. The threshold prior to perceptual adaption was obtained using responses of the last two blocks in the first session and the one following adaptation was obtained using the first two blocks in the third session. Two subjects were excluded since their changes were out of the range for average ± 3SD of the rest of group. When we compared perceptual thresholds prior to and following perceptual adaptation, the threshold changed to the direction of /e/ (-5.46 ± 1.04, average ± s.e.), indicating that the subjects perceived /a/ more than /e/ as an aftereffect of training. One-way ANOVA showed significantly different between sessions prior to and following the training ($F(1, 12) = 27.83$, $p < 0.001$). Our data suggest that repetitive exposure of somatosensory inputs during speech perception changes perceptual system and can support the idea that somatosensory input plays a role in speech adaptation.

Topic Areas: Speech Perception; Multisensory or Sensorimotor Integration

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Automated analysis of letter fluency data

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Introduction: The letter-guided fluency task is a measure of an individual's executive function and working memory. In clinical settings, the fluency score has been shown to be sensitive to neurodegenerative disease, psychosis, and other neurological conditions. However, a comprehensive analysis of letter fluency beyond the total score is still lacking; previous methods cannot be easily applied on a large scale due to reliance on manual assessments that are time intensive and require some level of expertise. To address this issue, we developed a novel automated method that is quantifiable and reproducible. We investigated how lexical and phonetic characteristics of words produced during the F-letter fluency task were related to the overall performance, inter-word response time (RT), and task duration, using this method. Methods: We recorded and transcribed 30-second digitized audio samples of F-letter-guided fluency tasks, produced by 76 young healthy participants (mean=20.1±1 years; 35 females). Using the transcripts, our automated algorithm counted the total number of correct "F" words produced and rated individual words for concreteness, ambiguity, frequency, familiarity, age of acquisition (AoA), and word length using published norms. The mean and standard deviation for lexical variables was calculated for each individual. A forced-aligner automatically aligned each transcript with the corresponding audio recording, and we measured word start time, word duration, and inter-word RT. Finally, we calculated articulation rate (syllable count per second), phonetic distance between two consecutive F-letter words (cumulative distance of the first 13 mel-frequency cepstral coefficients between the two words), and semantic distance (Euclidean distance between the vector representations of two consecutive F-letter words). Results: Total F-letter score significantly correlated with higher mean AoA (rho=0.38, $p<0.001$) and articulation rate (rho=0.24, p=0.034), and with lower mean word frequency (rho=-0.33, p=0.003), familiarity (rho=-0.24, p=0.035), word duration (rho=-0.26, p=0.023), and phonetic similarity (rho=-0.25, p=0.033). Total score was also positively correlated with an individual's standard deviation of AoA (rho=0.37, $p<0.001$), familiarity (rho=0.31, p=0.007), and phonetic similarity (rho=0.33, p=0.004). Thus better performance was associated with faster speaking rate, the production of less frequent, less familiar, higher AoA, and more phonetically similar words, and greater variance in AoA, familiarity and phonetic similarity of the words produced. Inter-word RT was negatively correlated with frequency (p=0.002) and ambiguity (p=0.006) of F-letter words, and was positively correlated with AoA (p=0.002), number of phonemes (p=0.006), phonetic distance ($p<0.001$) and semantic distance ($p<0.001$). Lastly over the course of the task, the frequency ($p<0.001$), ambiguity (p=0.003), and semantic distance between words (p=0.031) significantly decreased over time, whereas AoA ($p<0.001$) and the number of phonemes per word (p=0.045) increased. Conclusion: This study shows that the strategy that participants with high F-letter scores employ involves words' lexical and acoustic characteristics. This study also demonstrates the successful implementation of our automated language processing pipelines in a standardized neuropsychological task. This novel approach captures subtle and rich language characteristics during test performance that enhance informativeness. This work will serve as the reference for letter-guided category fluency production similarly acquired in neurodegenerative patients.

Topic Areas: Language Production; Computational Approaches

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Distinct Nodal Responses for Verbs in the Production Network

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Foundational studies by Damasio (PNAS, 1993) and Tranel (Brain and Language, 2005) suggest that lesions may result in selective impairments in the ability to produce specific word classes, namely nouns and verbs, leading to the concept that the retrieval and production of words for objects and actions engage unique substrates or network components. Neuroimaging studies have examined the neural correlates underlying such functions, but the spatiotemporal dynamics that separate these two processes are not fully understood. To resolve these questions, we used electrocorticographic recordings in a large cohort during visually-cued object and action naming tasks. Recordings from intracranial surface grid and stereotactic depth electrodes (n = 10730, 93 patients), implanted for pre-surgical evaluation of epilepsy were used to characterize the cortical network dynamics during noun and verb production. Patients performed picture naming of objects and actions along with a high-level control condition of scrambled images. A surface-based mixed-effects multilevel analysis (SB-MEMA) of broadband gamma activity yielded population maps of focal activity changes relative to baseline. We explored regional dynamics in three anatomically constrained nodes within the active regions: intraparietal sulcus, posterior middle temporal gyrus, and pars triangularis. A broad cortical network was recruited for both verb and noun naming. Immediately following picture presentation, cortical activity propagated along the dorsal and ventral streams to the intraparietal sulcus (IPS) and mid-fusiform gyrus, respectively; activity in the dorsal stream was uniquely prolonged during verb production ($p<0.001$). Next, cortical activity was observed concurrently in posterior middle temporal gyrus (pMTG) and a constellation of frontal regions: pars triangularis and opercularis, superior frontal sulcus, and supplementary motor areas. Pre-articulatory activity was uniquely observed in pMTG during verb production ($p<0.001$); post-articulatory activity in this region was matched between noun, verb, and control conditions. Pars triangularis (pTri) exhibited similar temporal dynamics in both noun and verb production, but this activity was significantly enhanced during verb production ($p<0.001$). Finally, peaks in cortical activity were observed in mouth sensorimotor and auditory cortex following onset of articulation. We found that the production of words from these two classes recruit the same language production network, but three critical nodes possess unique dynamics selective for verbs: (1) IPS has a longer duration of activity, (2) pMTG is active prior to articulation, and (3) pTri has a higher magnitude of activity. Our results demonstrate that object and action naming networks are overlapping but differentially activated, and identify distinct focal patterns of cortical activity specific to verb naming. This comprehensive view of category-specific production networks may aid in the development of novel therapies and interventions for aphasia.

Topic Areas: Language Production; Control, Selection, and Executive Processes

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Cognitive Control Associated with Noise-Induced Changes in Spoken Language Complexity

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To produce fluent and grammatically correct speech, speakers have been argued to engage in a monitoring process that involves some degree of cognitive control. The demand on cognitive control is likely to be even greater when speakers are subject to the additional burden of ignoring distracting auditory input in noisy environments. Moreover, under these circumstances, they may contend with the knowledge that listeners are also engaging in more effortful processing. Despite the prevalence of noise in everyday life, psycholinguistic research has largely focused on examining language production under optimal, relatively silent conditions. Those studies that have examined the effect of noise have largely done so at the acoustic level, centering on speakers' tendency to increase the loudness of their speech in noisy environments. To address this gap, the present study (1) measures how noise affects higher-level, non-acoustic properties of language production; and (2) investigates the extent to which these noise-induced changes are modulated by individual differences in cognitive control. Remotely through videoconferencing software, participants completed a picture description task during which they described a set of images under noise and silence conditions. Crucially, both the speaker (the participant) and their listener (the experimenter) were simultaneously exposed (or not exposed in the case of the silence condition) to the background noise, which consisted of multi-taker babble. Following the picture description task, participants completed a series of cognitive control tasks, each intended to tap into different aspects of cognitive control: the AX-Continuous Performance Task (AX-CPT), Flanker, and counting Stroop. Overall, background noise strongly affected language production, with speakers reducing the number of clauses, words, unfilled pauses, filled pauses, and mazes produced in noise relative to silence. Although performance on the AX-CPT and Flanker tasks was not significantly associated with noise-induced changes, performance on the Stroop task was correlated with the reduction of clauses, words, and unfilled pauses. Individuals who exhibited a greater reaction time interference effect on the Stroop (i.e., weaker cognitive control) produced fewer clauses, words, and unfilled pauses in noise. We consider this specific set of reductions to be speaker-oriented modifications implemented as a means of alleviating the cognitive burden of speaking in noise. However, we suggest that the reduction of filled pauses and mazes in noise, neither of which was correlated with cognitive control, to be listener-oriented modifications implemented as a means of facilitating comprehension for the sake of the listener.

Topic Areas: Language Production; Control, Selection, and Executive Processes

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Structural connectivity of human inferior colliculus subdivisions using in vivo and post mortem diffusion MRI tractography

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Inferior colliculus (IC) is a major computational hub along the ascending auditory pathway that transforms sound to meaning and is purported to play a large role in efferent control of auditory processing. Research in animal models suggests critical roles for the IC in auditory learning, particularly in auditory plasticity, egocentric selection, and noise exclusion. IC contains multiple subdivisions, including central nucleus (receiving ascending inputs) and external and dorsal nuclei (receiving more heterogeneous inputs, including descending and multisensory connections). However, subdivisions of human IC have been challenging to identify using standard brain imaging techniques such as MRI, and the connectivity of each of these subnuclei has not been identified in the human brain. In this study, we estimated the connectivity of human IC subdivisions with diffusion MRI (dMRI) tractography. We used anatomical-based seed analysis as well as data-driven clustering, which provide converging evidence for distinct connectivity profiles for each of the IC subdivisions. Two unique datasets were included in this study. The first is a post mortem human brainstem scanned with dMRI for 208 hours at b=4000 s/mm2 in 120 diffusion directions at 200 µm isotropic resolution. The second is a single in vivo participant scanned over 18 hours at b=1000 and 2500 s/mm2 in 1260 diffusion directions at 760 µm isotropic resolution. Both datasets also included anatomical MRI (post mortem: 50 µm T2-weighted; in vivo: 700 µm T1-weighted and T2-weighted). We conducted two analyses in each dataset. In the data-driven analysis, the entire IC was used as a tractography seed, and the resulting streamlines were partitioned using k-means clustering (k=5). In the seed-based analysis, IC subdivisions were manually labeled on the anatomical images, and tractography was run from each subdivision. In both the post mortem and in vivo datasets, k-means clustering isolated streamlines between IC and cerebral cortex and between IC and brainstem. Each of the clusters reached IC in a unique location: cortex–bound streamlines were centered on dorsal–rostral IC, while brainstem streamlines hit ventrolaterally. Overall, streamline clusters were largely consistent between the post mortem and in vivo datasets. Using anatomically defined IC subdivisions as tractography seeds, streamlines were less differentiated in the in vivo dataset than in the post mortem dataset, where streamlines reaching anatomically defined IC substructures had unique pathways. Compared to central and external nuclei, dorsal nucleus had fewer streamlines connecting caudally with brainstem through lateral lemniscus. However, dorsal nucleus had more streamlines connecting directly with medial geniculate (and beyond towards auditory cortex) than central or external nuclei, agreeing with the data-driven k-means clustering results. In summary, using sub-millimeter diffusion MRI from high quality datasets, we investigated substructure connectivity patterns of human inferior colliculus. With data-driven approaches to cluster white matter connections through IC, we found that streamline clusters reached IC in distinct locations. The results aligned with connectivity patterns based on tractography analysis using anatomically defined IC subdivisions. Taken together, the data-driven and anatomically driven analyses demonstrate that diffusion MRI tractography can reveal fine-grained structural connectivity patterns within the human subcortical auditory system.

Topic Areas: Methods; Perception: Auditory

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The language network and the executive control network are distinct in bilinguals

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The brain networks that support language comprehension vs. executive control have been shown to be robustly dissociated in monolinguals (e.g., Fedorenko et al., 2012; Monti et al., 2012; Blank et al., 2014; Mineroff et al., 2018; Braga et al., 2020). However, the relationship between language processing mechanisms and domain-general executive control mechanisms in bilinguals remains debated. Some have explicitly argued that these mechanisms are more integrated/overlapping in bilinguals, with some parts of the language network, within the left inferior frontal cortex, supporting executive functions (e.g., Garbin et al, 2010; Coderre et al, 2016). However, empirical support for the latter claims comes from brain imaging studies that rely on averaging individual activation maps in the common space and drawing inferences from the group-averaged map. This approach can underestimate the separation between nearby functionally distinct areas given the inter-individual variability in the precise locations of these areas (Nieto-Castañón & Fedorenko, 2012). We investigated the relationship between the language network and the domain-general executive control (Multiple Demand (MD); Duncan, 2010) network using the individual-subject analytic approach. We used relatively large and carefully matched samples of early balanced bilinguals (n=80) and monolinguals (n=73) who completed a sentence comprehension task (Fedorenko et al., 2010) and an executive (spatial working memory) task, which has been previously established to be an effective 'localizer' for the MD network (Shashidara et al., 2019; Assem et al., 2020). We defined the language and the MD network in each individual, and then examined their responses to the two tasks using across-runs cross validation to ensure independence (Kriegeskorte et al, 2009). We found that the two networks are as robustly dissociated in the bilinguals as they are in the monolinguals: the language-responsive regions showed no response to the working memory task, and the MD regions showed a stronger response to the meaningless and unstructured control condition (nonword sequences) than to sentences. Interestingly, we observed overall stronger responses to the working memory task conditions, and a larger difference between the harder and the easier conditions, in the MD network of the bilinguals compared to the monolinguals. Given that stronger responses and a larger hard>easy effect have been linked with superior behavioral performance on executive tasks and a higher IQ (e.g., Assem et al., 2020), these results are compatible with the idea of superior executive abilities in bilinguals (e.g., Bialystok, Craik & Luk, 2012). That said, directly linking this difference to differences in linguistic experiences is challenging. Critically, even though differences in the MD network's functionality in the two populations deserve further investigation, this network is robustly dissociated from the language network, even though the two lie side by side in the inferior frontal cortex (Fedorenko & Blank, 2020). More generally, this work highlights the importance of subject-specific analyses in the study of bilingualism, especially given the focus on the relationship between cognitive mechanisms that are supported by closely adjacent networks, and the well-established inter-individual variability in their precise locations in the frontal cortex (e.g., Frost & Goebel, 2011; Tahmasebi et al., 2012).

Topic Areas: Multilingualism; Control, Selection, and Executive Processes

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The white matter correlates of domain-specific working memory

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Introduction Prior evidence suggests separable, domain-specific working memory (WM) buffers for maintaining phonological (i.e., speech sound) and semantic (i.e., meaning) information. The phonological WM buffer's proposed location is the left supramarginal gyrus, whereas semantic WM has been related to the left inferior frontal gyrus, middle frontal gyrus, and angular gyrus. Here we investigated the role of white matter tracts connected to these regions in supporting WM. The left AF, previously implicated in verbal WM, connects the supramarginal gyrus, the proposed location of the phonological store, to frontal regions supporting rehearsal. The IFOF, ILF, MLF, and UF connect temporal regions representing semantics to regions such as the angular gyrus or inferior frontal gyrus which may be involved in maintaining semantics. Thus, we predicted left AF integrity to relate to phonological WM and left IFOF, ILF, MLF, and UF integrity to relate to semantic WM. Methods For 24 individuals with aphasia following left hemisphere brain damage, behavioral scores were available on single word processing (picture-word matching with phonological and semantic distractors), phonological WM (digit matching span; mean 4.03, sd 1.12), and semantic WM (category probe span; mean 1.73; sd .71). T1 and diffusion weighted (b = 800 sec/mm2) scans were obtained for each participant. Left and right hemisphere tracts of interest were dissected with ROIs drawn manually in native space. Results Bivariate correlations between fractional anisotropy (FA) values and behavioral measures were computed, and a multiple regression approach was used to test the relationship between FA and WM, while controlling for single word processing ability. The left AF could only be segmented for 7 participants, and thus correlations with behavioral measures were not computed. For the remaining tracts, segmentation was possible for 13-24 participants. In the left hemisphere, the only correlations with at least marginal significance were for single word semantic processing and FA values for the MLF and UF. In the right hemisphere, FA values for the IFOF correlated with single word phonological processing, and FA values for the IFOF, ILF and UF correlated with semantic WM. In the multiple regressions controlling for single word processing, the relations between semantic WM and FA values remained marginally significant for the right ILF and UF (both p's=.054). Conclusion We did not observe expected relationships between WM and left hemisphere white matter tract integrity, though others have reported a relationship between left AF integrity and verbal WM; however, we had a limited ability to segment the left AF. Future work is needed to assess a larger sample of participants and analyze relationships between WM and subsections of the AF as only certain subsections of the AF (e.g., the direct segment, directly connecting temporal and frontal regions) may relate to phonological WM. The right ILF and UF relations to semantic WM were a novel result and suggest possible reorganization to the right hemisphere. To address these tracts' role prior to brain damage, we will investigate correlations between integrity of these tracts and WM performance in healthy age-matched individuals.

Topic Areas: Phonology and Phonological Working Memory; Meaning: Lexical Semantics

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Multivariate decoding of neural representations for verbal working memory

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The nature of the representational code underlying verbal working memory rehearsal has long been debated. Arguments for the primary importance of "acoustic", "articulatory", or "phonological" codes for verbal working memory have variously been advanced (e.g. Wickelgren 1965; Hintzman, 1967; Baddeley, 1992). With the advent of cognitive neuroscience and neuroimaging, the brain areas supporting verbal working memory were identified, often with the tacit assumption that neural activity identified during memory rehearsal was, somewhat generically, “phonological”. In the current study we attempted to examine both the “where” and “what” of verbal working memory representations by using a multivariate decoding approach with functional magnetic resonance imaging (fMRI). In this study, 18 participants performed three tasks in separate scanning sessions. In one of the first two sessions, subjects performed a passive auditory listening task in which they were repeatedly presented with 12 CV syllables consisting of the consonants /b/, /d/, /p/, and /t/ crossed with the vowels/a/, /i/, and /u/. In the other of the first two sessions, participants performed an articulation task, in which, when presented with the written form of one of the above syllables (e.g. “ba”), they were asked to silently mouth the cued syllable four consecutive times in synchrony with a flashing dot. These two fMRI datasets were then used to train a series of multivariate pattern classifiers that could discriminate between the set of 12 syllables. On the third scan, subjects performed a simple verbal working memory task in which they were presented auditorily with two syllables in succession (500 ms ISI). After a 1000 ms delay, they received a retro-cue in the form of a circle appearing on either the left or right side of the screen. If the circle appeared on the left, the task was to rehearse the syllable that was just presented in the left ear and vice versa for the right. After a 10 s delay, participants were prompted to overtly recall the cued syllable and were recorded using an optical microphone installed in the scanner. Data analysis focused on the 10 s delay interval intervening between stimulus encoding and recall. Using a multivariate searchlight approach with the classifier trained on the auditory perception data, we could successfully decode the cued syllable in the mid portion of the superior temporal gyrus (STG), bilaterally. However, we also found that using the classifier trained on the “silent mouthing” data, that we could also the decode cued syllable in the STG--with even better accuracy than for the auditory classifier. This suggests that the neural representations identified in the STG are likely the result of motor-to-sensory feedback that arises during subvocal rehearsal, rather than as a frank “acoustic-sensory” representation. In addition, the regions of the STG that showed significant syllable classification did not tend to show sustained univariate activity during the delay, and thus that these neural signals would have been “missed” by more conventional approaches.

Topic Areas: Phonology and Phonological Working Memory; Multisensory or Sensorimotor Integration

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A weak shadow of early life language processing persists in right hemisphere frontal and temporal cortex of the mature brain

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The language system is strongly lateralized to the left hemisphere (LH) in the majority of adults. However, language activity is more bilateral in young children. Indeed, when a stroke in infancy irreversibly damages left perisylvian regions, language is acquired successfully in right perisylvian regions, while a similar stroke in adulthood devastates language abilities. How then do right hemisphere (RH) frontal and temporal regions transition from being 'equipotential' for language processing early in life to being unavailable for language processing in the mature brain? Prior work has demonstrated a significant reduction in RH language activation in adults, but we cannot discern from these findings—based on measures of activation magnitude—whether there is a change in the spatial organization of language homologues in the RH. In this study, we investigated the activation pattern of RH regions that are homotopic to typical LH language centers during language processing in healthy children and adults. We hypothesized that after the amount of activity is equated in both hemispheres, if the spatial organization of language activity was just as symmetrical in adults as it was in young children, then a "weak shadow" of early life language processing may persist in the adult RH. Children aged 4-13 (n=39) and young adults (n=14) completed an auditory sentence comprehension fMRI task. To equate activity, we applied fixed cutoffs for the number of active voxels (ranked by t-value) that would be included in each hemisphere for every participant. To evaluate homotopicity, we generated left-right flipped versions of each activation map, calculated spatial overlap (Dice Coefficient) between the LH and RH activity in frontal and temporal regions, and tested for mean differences in the spatial overlap values between the age groups. We found no statistical differences between the age groups in homotopic activation overlap for the frontal or temporal regions. In other words, the spatial organization of language activity was just as symmetrical in adults as it was in young children. These results indicate that homotopic regions in the RH may still be available for language processing to some degree in adults. After a LH stroke in adulthood, recovering some or all of the early-life activation in these regions might be relevant to enhancing recovery of language abilities.

Topic Areas: Development; Methods

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Predictive Validity Comparison for Multivariate Lesion-Behavior Maps

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Introduction. Multivariate lesion-behavior mapping (LBM) provides a statistical map of the association between patterns of brain damage and individual differences in behavior. To understand whether behaviors are mediated by distinct brain regions, researchers often compare LBM beta weights by either the subtraction method (emphasizing differences) or the correlation method (emphasizing similarity). However, both methods lack a principled way to determine LBM distinctness and are disconnected from a major goal of LBMs: predicting behavior from brain damage. Without such criteria, researchers may unwittingly draw conclusions from numeric differences between LBMs that are irrelevant to predicting behavior from brain damage. Here, we developed and validated a Predictive Validity Comparison (PVC) method that establishes such a criterion. Method. The PVC method conceptualizes the LBM comparison problem as a choice between two hypotheses: Under the null hypothesis (H0), individual differences across two behaviors are the result of a single lesion pattern (+ noise). Under the alternative hypothesis (HA), individual differences across behaviors are the result of distinct lesion patterns. The method fits multivariate LBMs under each hypothesis (one under H0; two under HA) using SCCAN (Pustina et al., 2018) and compares their predictive accuracy. If the predictions under HA are better than under H0 (using Akaike Information Criterion; AIC), we conclude that separate LBMs better fit the behaviors. Otherwise, only a single LBM is needed. To assess the practical utility of PVC, we compared it with common LBM comparison methods, the subtraction and correlation methods, using published lesion-behavior stroke datasets with either highly similar behaviors (r=0.89, Moss Rehabilitation Research Institute Data, MRRI) or highly dissimilar behaviors (r=-0.02; Ding et al., 2020). Second, we validated PVC using region-of-interest based simulations. Two simulated behaviors were derived from proportion damage in one (33 simulations) vs. two (666 simulations) Brodmann regions using the MRRI data set. Results were organized by the regional proportion damage across subjects and between-region damage correlations. Results. For similar behaviors (MRRI dataset), PVC concluded only a single LBM was necessary (AIC difference -382 in favor of H0); for dissimilar behaviors (Ding et al. dataset), PVC concluded separate LBMs were necessary (AIC difference 372 in favor of HA). In contrast, the subtraction and correlation methods provided indeterminate results, lacking clear decision thresholds and showing strong sensitivity to LBM-fitting parameters. On simulated data, PVC had 94% sensitivity (accurately determining behaviors had distinct neural bases) on high-powered regions (>=10% of participants had >=5% damage to both regions; n=300) and 96% sensitivity on low-powered regions (n=366). Sensitivity depended on the between-region damage correlation, near ceiling for low to moderate correlations, but near the floor for extreme correlations (>0.7), although these were rare (n=31). Specificity (accurately determining behaviors had a shared neural basis) was excellent for both high (100%; 25/25 correct) and low-powered regions (92%; 7/8 correct). Conclusion. The PVC method’s excellent performance with real and simulated data facilitates principled determination of LBM distinctness. With this advance, researchers can better determine whether individual differences across two behaviors arise from distinct lesion patterns.

Topic Areas: Methods; Disorders: Acquired

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Language experience modulates functional connectivity at rest in deaf individuals

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Early sensory and language experience can modulate brain reorganisation (Manini et al., 2021). Studies on deaf individuals have demonstrated that reorganisation can extend beyond the sensory cortices (Cardin et al., 2018). Functional connectivity has also been shown to be reshaped by early sensory experience (Bonna et al., 2020). Previous work on functional connectivity and language in deaf individuals has not distinguished the language experience of deaf people from their sensory experience (Malaia et al., 2014). The aim of the current study is to directly investigate the effect of language experience on functional connectivity at rest in deaf individuals. 25 congenitally or early deaf participants took part in the study. Participants had different language backgrounds, which is reflective of the heterogeneity in language experiences observed in the deaf communities. Their language skills were measured using British Sign Language Grammaticality Judgement (Cormier et al., 2012) and English Grammaticality Judgement tasks and were combined into a single, modality-independent measure of language proficiency (Manini et al., 2021). Data were collected during resting-state scans of approximately 10 minutes in length. The neuroimaging data were preprocessed using a standard pipeline in SPM12. The Schaefer-Yeo 2018 atlas (Schaefer et al., 2018) was used to conduct the connectivity analysis in Conn, with a number of seeds reassigned to a different network in order to create separate language and auditory networks. The general language proficiency measure was used as a second-level covariate. The analysis revealed significant effects of language proficiency ($pFDR < .05$) on the functional connectivity between various networks. Deaf individuals who had higher general, modality-independent language proficiency scores showed increased connectivity between the visual network and a number of other networks, including the salience / ventral attention, dorsal attention, somatomotor, control, temporoparietal, and language networks. The pSTS/pSTG seed from the language network revealed predominantly increasing connectivity to the salience / ventral attention network in individuals with higher language scores, while the connectivity with the control and the DMN decreased. The study demonstrated extensive influence of language proficiency on various large-scale resting-state networks, highlighting the role of language experience in organisation of networks beyond the temporoparietal and language networks in deaf individuals. We have demonstrated that in participants with higher language scores, independently of language modality, connectivity of the visual network is stronger than in participants with lower language scores. The enhanced connectivity of the visual network with the language network in participants with better language proficiency scores can indicate increased involvement of the visual system in communication processes. The enhanced connectivity of the salience network with seeds from the visual and language networks may reflect the increased role of the salience network in detecting visual stimuli and in situational awareness during communication in these participants. Taken together, the findings demonstrate how early language experience modulates connectivity between different areas in the brain, including those beyond the typical language and the sensory areas.

Topic Areas: Signed Language and Gesture; Multilingualism

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Synchronized brains: The neurobiological mechanisms for cooperative success *Sandbox Series*

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To achieve successful cooperation, mutual conceptual alignment -a state where the mental representations of individuals are aligned- is needed. Conceptual alignment then leads to mutual understanding where individuals implicitly reach an agreement on the meaning of an idea (Stolk et al., 2016). In order to investigate the neurobiological mechanisms that underlie cooperation, simultaneous electroencephalography activity in two cooperating partners (i.e. EEG hyperscanning) is being recorded in an ongoing study with the EEG data collection having only just started. Non-verbal (task 1) and verbal (task 2) cooperation tasks are used to examine the relationship between brain-to-brain synchrony (i.e. activity in one brain that is correlated with activity in another brain) and the degree of cooperative success (i.e. formation of mutual understanding as measured by successful cooperative performance). More specifically, in task 1 we examine the emergence of non-verbal mutual understanding that leads to cooperative success. Cooperative partners are instructed to synchronise their button presses (press their buttons within 250ms of each other) after hearing an auditory cue. Participants wait a short/medium/long amounts of time after hearing a high/medium/low frequency tones respectively. Cooperative partners need to converge on the meaning of ‘short/medium/long’ by adjusting their responses (i.e. their wait time before pressing the button) based on feedback they receive after each trial. Behavioural pilot data (N=17) of the interpersonal time lag (i.e. normalised time difference between partners’ button presses) were analysed as a function of trial progression throughout the experiment. The interpersonal time lag was negatively correlated with the trial number ($r(298) = -.39$, $p < .001$), suggesting that participants were able to learn to cooperate with each other more effectively as the task progressed. Task 2 is exploring the effect of verbal communication on conceptual alignment that leads to cooperative success. During the task, each participant within a dyad has a distinct role. Participant 1 (P1) is presented four (target) symbols, which they describe to participant 2 (P2). P2 is presented six columns with 8 symbols in each column. P2 is to find the (target) column that contains all four symbols (amongst distractor symbols) described by P1 and to say the order that the target symbols appear in in the column (omitting the distractor symbols) from top to bottom. P1 then needs to click on the symbols in the order told by P2. Cooperation is successful when all of the symbols on P1’s screen are clicked in the correct order within the time limit of the trial. For both tasks, we will use phase-lag-based connectivity analysis to examine the brain-to-brain synchrony between the cooperating partners. We predict that the degree of brain-to-brain synchrony will be greater in trials where mutual understanding/ cooperative success is achieved compared to cooperative failure trials.

Topic Areas: Methods; Language Production

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Does the connectivity within the right hemisphere predict variability in verbal repetition abilities in post-stroke aphasia? *Sandbox Series*

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Language function has traditionally been attributed to the activity of perisylvian areas in the left hemisphere. However, the role of the right hemisphere in language is still an object of debate, with recent studies pointing towards an important impact of this hemisphere in certain tasks and in language recovery in post-stroke aphasia (loss or impairment of language due to brain damage after stroke, [PSA]). Verbal repetition is often affected in acquired (PSA) and degenerative language disorders (primary progressive aphasia, [PPA]) and its functional characterization is relevant since it may directly inform rehabilitation strategies. At brain level, repetition of unknown words and pseudowords has been related to the activity of the arcuate fasciculus (direct and indirect segments) as main dorsal pathways, whereas repetition of known words and sentences has been linked to the ventral system. Investigations regarding verbal repetition and its brain correlates have mainly focused on the left hemisphere, however after brain damage in the language-dominant hemisphere, interindividual variability in verbal repetition abilities is frequent and can be related to the function and structure of the contralateral dorsal and ventral systems. Additionally, studies on verbal repetition in PSA and PPA should correlate the status of function with different stimuli (words, pseudowords, novel and idiomatic phrases, sentences) to explore the underlying mechanisms in a more comprehensive way. This study aims to characterize structural and functional correlates of verbal repetition deficits in the right hemisphere of patients with chronic PSA due to left perisylvian involvement by combining MRI-based T1-weighted imaging, diffusion tensor imaging (DTI), and resting state functional MRI (rs-fMRI).To achieve this, repetition of words, pseudowords and sentences will be evaluated in a sample of 20 persons with chronic PSA (10 women). MRI with T1-weighted imaging, DTI, and rs-fMRI will be acquired in order to perform functional and structural connectivity analyses of the dorsal and ventral streams. DTI will be used to perform tractography analyses of the direct and indirect pathways of the arcuate fasciculus (dorsal pathway), and the ventral pathways (inferior fronto-occipital fasciculus, inferior longitudinal fasciculus, uncinate fasciculus). rs-fMRI will be used to measure functional connectivity strength between the areas connected by the studied dorsal and ventral pathways (i.e., inferior frontal gyrus, angular and supramarginal gyri and posterior middle and superior temporal gyri). Analyses will be performed bilaterally. Data acquisition is currently still ongoing. Results will provide important insights on the role of the non-dominant hemisphere in verbal repetition, allowing to gain a more holistic comprehension of how language is processed in the brain and leading to new information about language recovery in people with PSA that may guide therapeutic interventions.

Topic Areas: Disorders: Acquired; Language Production

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Longitudinal lesion-symptom mapping of recovery of expressive grammar in aphasia *Sandbox Series*

Veronika Vadinova[1], Aleksi Sihvonen[1], Kim Garden[1], Kate O'Brien[1], Tracy Roxbury[1], Greig de Zubicaray[2], Marcus Meinzer[3], Katie McMahon[2], David Copland[1], Sonia Brownsett[1]; [1]University of Queensland, [2]Queensland University of Technology, [3]University Medicine Greifswald

Introduction: Previous lesion-symptom mapping (LSM) studies have suggested that a large network of regions, incorporating frontal and temporal, and cortical and subcortical regions, are associated with grammatical impairments when using tools designed to specifically assess discrete componets of grammar (e.g., sentence production task) (Ouden et al. 2019, Lukic et al. 2021). However, such discrete measures do not assess a person’s ability to generate and produce grammatically correct speech during realistic communicative scenarios. For the purpose of this study, we define the ability to produce grammatically correct speech during such a scenario as 'expressive grammar'. One approach to evaluating expressive grammar in aphasia is through the assessment of its production during Connected Speech (CS) samples. LSM studies that have used CS to focus on grammatical impairments, have typically invetigated surrogate measures, such as mean length of utterance (MLU) or proportion of closed-class words (Borovsky et al. 2007, Mirman et al. 2019). Importantly, all LSM studies of CS to date have been conducted in chronic post-stroke aphasia, beyond the period of spontaneous recovery. The neural correlates of expressive grammar deficits in early post stroke aphasia remain unknown. Longitudinal LSM analyses, that illuminate the neural correlates of favourable versus unfavourable chronic recovery of a given function, are also missing. In contrast to single timepoint LSM analyses, longitudinal LSM studies investigate the relationship between anatomical damage and the change in impairment between the early and chronic time-points (i.e., recovery index score) (Karnath al. 2011). Research question & Hypotheses: We aim to assess grammatical properties of CS in a group of Individuals With Aphasia (IWA) that have been followed up from early subacute to chronic stage of recovery. We hypothesize, based on evidence yielded in previous studies, that damage to left-hemisphere frontal white matter (particularly the arcuate fasciculus) and several temporal cortical regions (particularly the superior temporal gyrus) will play a pivotal role in unfavourable recovery of expressive grammar in chronic aphasia. In addition, we hypothesize that the neural correlates of early and chronic expressive grammar deficits may differ as a reflection of successful behavioural recovery in some IWA. Methods: 38 IWA a) experienced a single left hemisphere stroke and were diagnosed with aphasia, b) English as first language, and c) had a 3D T1- weighted image acquired at baseline. Lesion masks were manually delineated on T1 sequences. IWA completed the Western Aphasia Battery picture description task at two timepoints: early-subacute stage (2-6 weeks poststroke) and chronic stage (6 months poststroke). CS samples were transcribed, and the Computerized Language Analysis software (CLAN) was used to derive the grammaticality measure (MLU x proportion of grammatical errors). To examine lesion-symptom associations, we will apply a multivariate method, support vector regression LSM (SVR-LSM) (Zhang et al. 2014). We aim to control for the influence of lesion volume, education, naming and white matter hyperintensities. Several SVR-LSM models will be built to explore a) the anatomy of early expressive grammar deficits; b) the anatomy of chronic expressive grammar deficits; c) the anatomy of recovery of expressive grammar deficits.

Topic Areas: Disorders: Acquired; Syntax

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The benefits of regular physical exercise training for brain structure and function in relation to tip-of-the-tongue states in healthy ageing *Sandbox Series*

Foyzul Rahman[1], Samuel J.E. Lucas[1], Eunice G. Fernandes[2], Allison Wetterlin[2], Hilde Lohne-Seiler[2], Sveinung Bernsten[2], Sindre Fosstveit[2], Linda Wheeldon[2], Katrien Segaert[1]; [1]University of Birmingham, UK., [2]University of Agder, Norway.

Regular physical activity is protective against age-related decay of executive function, including working memory and inhibitory control (Weinstein et al., 2012). Further, studies have shown that longitudinal aerobic exercise training interventions in older adults is associated with greater total brain volume, in both grey and white matter regions (e.g., Colcombe et al., 2006). However, it is unclear whether these benefits extend beyond executive function. What is currently lacking is knowledge about the effects of exercise on language abilities in healthy ageing. Many language processes are isolated from, and independent of, other cognitive faculties. For example, word finding difficulties are not age-associated failures of long-term memory, as word knowledge increases with age, but the ability to successfully access the words' phonological form decreases. Recently, we have demonstrated that while older adults generally experience more word finding difficulties relative to younger adults, fitter older adults experience fewer word finding difficulties than age-matched unfit older adults (Segaert et al., 2018). Building on this, for the first time in the literature, we will conduct a six-month, endurance-based exercise intervention where we will test linguistic and non-linguistic cognitive performance in exercising (treatment) and non-exercising (control) older adults, in addition to acquiring structural and functional brain data to investigate the neural changes underlying the benefits of exercise on language. To this end, pre- and post-intervention, we will collect executive function (e.g., processing speed, working memory, inhibition), language function (e.g., word finding or tip-of-the-tongue states [TOT]) and physical fitness/physical function (e.g., oxygen consumption, hand-grip strength) measures in healthy older adults. Collection of physical function data will allow us to quantify increases in fitness levels due to the intervention and map these alterations onto linguistic and non-linguistic performance. We will also acquire fMRI during a TOT task to highlight differential recruitment according to TOT vs. non-TOT states, between exercising and control participants. Additionally, we will acquire high-resolution T1 anatomical images to permit examination of grey matter density in key language areas (e.g., left insula) and conduct a perfusion sequence to obtain cerebral blood flow and volume. Potential changes in grey matter density and cerebral blood flow/volume will then be directly mapped onto the (predicted) behavioural benefits of improved physical fitness, afforded by the intervention. We will use a resting state sequence to utilise resting-state-fluctuation-amplitude to correct our fMRI data for variability in neurovascular coupling among our older participants. Overall, we aim to establish for the first time a causal relationship between physical exercise and ameliorated language decline in healthy ageing. The acquisition of neuroimaging will allow us to understand the neural consequences of increased physical fitness, first, as a standalone measure, but also as a key component in the relationship between increased physical fitness and the advantages it confers in linguistic and non-linguistic aptitudes.

Topic Areas: Language Production; Control, Selection, and Executive Processes

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Decoding the scope of planning in sentence production *Sandbox Series*

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The neurobiology of sentence production has been understudied compared to sentence comprehension. A recent study on the differences and similarities between comprehension and production found substantial overlap in the networks engaged by each modality, but the BOLD time course for the production and comprehension of the same sentences was different (Giglio et al., in revision). In particular, the BOLD response was found to peak earlier for more complex structures relative to simpler structures in production, whereas the opposite pattern was observed in comprehension. This dissociation likely reflects earlier event conceptualization in production than comprehension, in line with eye-tracking evidence showing an initial focus on event apprehension in picture descriptions and action encoding before speech onset (Griffin & Bock, 2000; Konopka, 2019). Picture-word interference tasks instead show that the verb is not planned before speech onset unless the object is said first (Momma et al., 2016). In the present fMRI study, we aim to provide new insight into the processes and representations engaged in different levels of sentence planning, from event conceptualization to grammatical and phonological encoding, using multi-voxel pattern analysis. We will run a sentence production study with a sentence recall paradigm. Participants read sentences word-by-word at a very fast pace (150 ms per word) and repeat the sentence aloud after a distraction task. This paradigm was previously shown to lead to the reconstruction of the sentence from the conceptual meaning rather than by verbatim memory (Potter & Lombardi, 1990, van den Velde & Meyer, 2014). The use of sentence recall allows for getting closer to production elicited from a conceptual thought held in memory as in natural speech, whilst maintaining high experimental control. The stimuli are sentences in active or passive voice. Agents and patients refer to people either playing sports or music, and performing either actions requiring contact (e.g. kicking, hitting) or involving perception (e.g. seeing, noticing: “the musician sees the athlete”). We will perform classification of subject, object and verb semantic categories in the time windows before speech onset to determine to what extent these concepts are processed before sentence initiation. In addition, we will investigate how specifically the thematic role of the subject is encoded before speech onset. This will be done for broad thematic roles across actions (subject as agent), as well as for the narrower noun-verb role conjunctions (e.g., subject as kicker), which were found to be distinct in a previous comprehension study (Frankland and Greene, 2020). This will allow us to learn more about compositional processing in production. Finally, we will zoom in on sentence initiation to gain insight into phonological, morphological, and syntactic encoding during speech. In particular, we will run representational similarity analysis to characterize the brain regions involved in representing different levels of sentence production without the use of task manipulations as usually performed in univariate fMRI designs.

Topic Areas: Language Production; Meaning: Combinatorial Semantics

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Tracking hierarchical processes in minimal linguistic phrases *Sandbox Series*

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Does meaning composition during language processing rely on hierarchical or linear computations? Using the frequency-tagging paradigm, Ding et al., (2016) reported that neural oscillations track the incremental combination of words into phrases, and phrases into sentences – that is, they track the unfolding of hierarchical linguistic structures. Yet, computational studies have shown that non-hierarchical models purely based on word-level lexical features could also explain earlier results, suggesting that linear computations may underlie meaning composition (Frank & Yang, 2018). Here we present the experimental design for a magnetoencephalography (MEG) study aimed at testing for the presence of hierarchical processes during minimal linguistic phrase reading. In this experiment, we will use the frequency-tagging paradigm with periodic presentation of written words. We will compare oscillatory responses to 3-word Noun Phrases (NPs) in Spanish containing either linear or hierarchical structures. In both the linear and hierarchical conditions, the first two words are identical (Noun and Colour Adjective; árbol rojo, tree red). The critical manipulation relies on the properties of the third word: in the linear condition, a Size Adjective (e.g., grande, big) modifies the Noun, while in the hierarchical condition a Degree Adjective (e.g., oscuro, dark) modifies the Colour Adjective – giving rise to an Adjective Phrase (AP). Crucially, this resulting AP is embedded within the NP, thus forming a hierarchical structure. By using NPs with identical syntactic categories in both conditions (Noun-Adjective-Adjective), our manipulation specifically targets differences in hierarchical structure, while ruling out potential confounds driven by lexical-category features. Spanish speakers will be presented with trials composed of sequences of 3-word NPs (eight NPs per trial) which instantiate either hierarchical or linear structures. Each word will be presented periodically for 0.5 s. The frequencies of interest will be 2 Hz for words, 1.33 Hz for AP, and 0.67 Hz for NP. After each trial, a picture will appear and participants will be asked to indicate whether or not it matches any of the NPs presented in the trial. This task represents a good proxy to assess whether participants deploy linear/hierarchical processing, as they have to access the compositional meaning of each NP in order to determine the match between its referent and the picture. MEG data will be analyzed through frequency-domain power analysis. We expect to observe power peaks corresponding to both the word and whole NP presentation frequencies in both conditions. Critically, if participants deploy hierarchical processing, we should find an additional peak at the AP frequency in the hierarchical condition, but not in the linear condition. This peak would reflect an extra computation required to access the overall compositional meaning of a hierarchical NP. We will present the experimental design of our study paired with simulations of expected results, as well as preliminary results from a pilot study designed to assess the feasibility of our task at the behavioral level.

Topic Areas: Meaning: Combinatorial Semantics; Syntax

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Proto-Language as a Structurer and Enhancer of Perception *Sandbox Series*

James Scott[1], Robert Foley[1], Mirjana Bozic[1]; [1]University of Cambridge

The evolution of the capacity for language is hotly debated. To date, much of the investigation has focused on the communicative functions of language. By contrast we examine the cognitive structuring consequences of language capabilities, which may have acted as a potential evolutionary route by providing an immediate adaptive advantage over ape communication. Language has been shown to enhance a variety of cognitive processes both on- and offline, including low level visual perception, and categorisation. Notably, these effects pertain to semantics without syntax. There has also been a resurgent interest in the concept of the non-arbitrariness of elements of language (iconicity). Iconicity may have provided an important foothold on the path to full-blown language by providing an immediate link between sound and meaning. Iconicity therefore renders the problem of language evolution less intractable, while links to embodiment and the cognition of other primates provide plausibility. The present study seeks to investigate language evolution by linking iconicity to the non-communicative functions of semantics. We hypothesise that early proto-words were iconic, and significantly structured cognition. This evolutionary route does not necessarily exclude communication as an additional selective pressure, and proximate function of language. To test this hypothesis, data were collected via an online game. First, new conceptual categories were created, consisting of animal-like visual stimuli which varied along four dimensions of shape and colour. This 4D tensor was then bisected to create two distinct categories, each containing several hundred exemplars which were more or less representative of the category. 141 participants were first trained on the new semantic categories using a protocol adapted from1. Participants were then tested using match to sample (MTS) and a novel ‘camouflage’ task. The former attempted to assess how the newly learnt categories affected visual recognition, including how participants responded to borderline stimuli and if the perceptual magnet applied here. The camouflage test used filters to distort stimuli, in an attempt to access lower levels of the visual cognition hierarchy, which have previously been shown to be affected by top-down semantic influence. Inter-participant conditions varied by the nature of an auditorily presented verbal label, in both training and testing phases of the experiment. In training, stimuli were paired with either an iconic pseudoword label; a non-iconic pseudoword label; or no label. The same conditions were used in the test phase, though half participants from labelled training conditions received no label in testing. This was to distinguish between the online and offline effects of labels. We predicted that both learning and testing performance would be significantly enhanced by iconic labels, both on- and offline. Hence, participants both trained and tested on iconic labels would perform best. Participants trained and tested on non-iconic labels were expected to do better than those in no label conditions. Pilot data tentatively support these predictions; full analyses still are ongoing.
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Topic Areas: Meaning: Lexical Semantics; History of the Neurobiology of Language

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An MEG Investigation of Category Ambiguous Words' Number of Roots and the Homonymy/Polysemy Distinction *Sandbox Series*

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[INTRODUCTION] A pervasive feature of language is lexical ambiguity, where words have many meanings (homonyms) and/or senses (polysemes). English ambiguity extends to syntactic category; stems can serve as nouns or verbs (the/to clash). Some theories treat category ambiguity like derivational morphology--(null) categorizing affixes follow roots (Hypothesis 1). Lexicalist accounts treat noun-verb ambiguous words as distinct lemmas (Hypothesis 2). Further, if polysemy and homonymy are representationally different, Hypothesis 1 would assign one root to polysemous noun-verb pairs (clash) but two to homonyms (duck) (1A). If the difference is a matter of degree, both types share a single root (1B). Some previous work suggests homonyms and polysemes are distinct, citing evidence for a facilitatory polysemy and inhibitory homonymy effect. This study (in preliminary stages due to COVID) finds evidence for 1B: one root for noun-verb ambiguous stems across homonymy and polysemy. [PREDICTIONS] Previous single word recognition MEG studies showed an effect of subcategorization entropy in ATL at 200-300ms PSO (M250). Hypothesis 1 predicts that form-based noun-verb entropy (higher entropy = noun and verb forms have more equal frequencies) coincides with subcategorization and derivational family entropy effects, all reflecting uncertainty over syntactic category continuations from the stem. 1A predicts number of meanings (homonymy) and senses (polysemy) have opposite effects on M350 (=N400m) responses, while 1B predicts the same effect direction. [METHODS] During a visual lexical decision task, we recorded brain activity from 11 adults using magnetoencephalography (MEG). The stimuli were 631 monomorphemic, monosyllabic, noun-verb ambiguous English words having a lexical decision accuracy > 80% plus 631 matched non-words. [RESULTS] We identified an earlier and later peak corresponding to the M250 and M350 in average activity across all items and subjects. For each trial within each subject, we averaged 50ms of activity centered on the group average peaks in corresponding ROIs. These averages were used in linear mixed effects models for further analysis. [M250] The anterior MTG ROI showed an effect of derivational entropy (estimate=-1.601, p=0.002) and noun-verb entropy (estimate=-2.985, p=0.032). [M350] At 360ms there was a negative peak with two larger, more distributed spatial components in anterior STG and MTG. In STG, there was an effect of log word frequency (estimate=-1.933, p<0.001) and number of meanings (estimate=-1.587, p=0.016). In MTG, there was an effect of log word frequency (estimate=-2.264, p<0.001) and number of senses (estimate=-0.133, p=0.038). Crucially, there was no noun-verb entropy and number of meanings interaction. [CONCLUSION] We find support for Hypothesis 1B: noun-verb ambiguous words are represented as a single item and categorized later with a null affix. We find early derivational and noun-verb entropy effects around 250ms (both reflecting potential affixation of category to a stem), and a later word frequency effect around 360ms indicating continuing lexical access. Number of senses and meanings had inhibitory effects, and there was no noun-verb entropy and number of meanings interaction, suggesting homonyms and polysemes are not represented differently.

Topic Areas: Meaning: Lexical Semantics; Morphology

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The influence of contextual variability on learning novel words: Does the type of variability matter? *Sandbox Series*

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Adults predominantly learn new vocabulary incidentally, from reading. Several studies indicate that contextual variability benefits such learning. However, we do not know what features of variability underlie this facilitation. Often, context variability is operationalized as the number of unique documents a new word appears in, or as the number of different topics covered by the texts. In addition to studies on textual variability, studies with young children suggest that visual variability benefits learning of object words. In particular, variability in irrelevant object features help children determine the core features of objects, which may support generalization and retention. In the current study, we examine the effects of two types of variability on the learning and retention of novel object words in narrative contexts. Specifically, we manipulate variability in situational contexts in which new objects are experienced (location, characters, activities) and variability in irrelevant object-features (color, size, texture). Narratives are optimal for comparing situation-related and object-related variability manipulations, as they invite the reader to build a mental simulation of the contexts. Web-based behavioral experiments will be conducted with English-speaking adults, across two sessions. In session 1, participants will encounter 16 novel words in learning blocks of three consecutive short fictional narratives of approximately 50 words each. Stories will either display high variability in non-definitional object features (e.g. color, size; Condition A), high variability in (non object-related) situational features (e.g. people, location; Condition B) or high variability in both object and situational features (Condition C). In a control condition, the same story will be repeated three times (Condition D). A fourth of the target words will be randomly allocated to each condition. Immediately after reading the three narratives, participants will be asked to define the word. The semantic features given in these definitions will be the outcome of interest. Ratings of participants' engagement in each narrative will also be collected. In session 2 (follow-up), two weeks later, participants will complete three additional tasks: a lexical decision task, an open-ended definition task (identical to session 1) and a multiple-choice task where the participants will be asked to (a) select the words' core semantic features, and (b) judge the acceptability of non-core semantic features. The analyses will examine our main hypotheses: 1) The variability conditions (A-C) will lead to improved retention of both word form and meaning, as evidenced by increased accuracy in lexical decision and greater definition knowledge. 2) Words learned in the object variability conditions (B + C) will lead to recall of a larger number of core features, and higher acceptance of irrelevant features (generalization) in the multiple choice task at follow-up. 3) Words learned in the situational variability conditions (A + C) will foster decontextualized knowledge, and will be associated with higher engagement at immediate post-test, in turn leading to better memory performance at follow-up. We will present pilot data from the behavioral experiment, which will serve as the foundation for an electroencephalography experiment aiming to track the neural correlates of word learning under the influence of contextual variability.

Topic Areas: Meaning: Lexical Semantics; Reading

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Age-related changes in semantic processing: towards a neurophysiological marker of early Alzheimer's disease *Sandbox Series*

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Early detection of Alzheimer's disease (AD) is crucial for delaying the disease progression. Synaptic dysfunction, measurable with neurophysiological imaging methods, is one of the earliest markers of AD pathology (Terry et al., 1991, Annals of Neurology, 30(4), 572–580). Noninvasive neurophysiological recordings of synaptic functioning using magnetoencephalography (MEG) could thus provide valuable tools for early detection of AD. To enable patient MEG studies, we need robust tasks able to differentiate AD-related deterioration from normal aging-related effects. Language processing serves as an ideal domain to study cortical aging effects, as it remains relatively well preserved in normal aging (Shafto & Tyler, 2014, Science, 346(6209), 583–588). Here, our goal is to develop a language task that is sensitive to the effects of normal and abnormal aging and feasible for later patient studies. To do so, we investigated age-related neurophysiological changes in a semantic priming task using MEG in healthy volunteers of different age groups. The N400 effect in semantic priming tasks typically gets weaker and slower in older subjects (Kutas & Iragui, 1998, Electroencephalography and Clinical Neurophysiology 108, 456–471), and the process is further affected in patients with Alzheimer's disease (Iragui et al., 1996, Electroencephalography and Clinical Neurophysiology 100, 392–406). We will measure 25 young (age 22–32) and 25 elderly (age 63–70) Finnish-speaking adults. In order to assess test-retest reliability, each participant is measured on two separate days. Structural MRIs are available from all subjects. According to our preliminary results (10 old and 13 young participants), there were notable differences between the age groups both in MEG activations and behavioral measures. A significant ($p<0.05$) N400 effect was observed in both subject groups on both measurement days. As expected, the N400 latency was longer for old than young participants: the difference was significant in the second measurement ($p=0.008$) and approached significance on the first measurement day ($p=0.06$). Surprisingly, despite the greater N400 latency, behavioral reaction times were considerably faster for older participants. This finding speaks for a difference in cognitive strategies between age groups. Task-related increase in frontal activation was observed in the older participants, possibly indicating more prominent use of compensatory top-down cognitive strategies (Wlotko et al., 2010, Linguistics and Language Compass, 4(8), 623–638). Our preliminary results suggest that the semantic priming task produces a reproducible N400 effect in both age groups and may provide a MEG biomarker for aging in the language domain. The results also establish a strong foundation for further developing the methodology toward clinical studies.

Topic Areas: Methods; Meaning: Lexical Semantics

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The roles of blind “visual” cortex in language processing: insights from fMRI and TMS studies *Sandbox Series*

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Neuroplasticity is characterised by functional and anatomical brain reorganisation driven by environmental demands. It occurs in response to experiences like sensory deprivation or intensive training and can cross boundaries between the senses. For example, the visual cortex of blind subjects can respond to tactile or auditory stimuli in a functionally specific fashion. Recent results suggest that reorganisation could be also observed in sighted subjects after demanding learning, raising the question about sensory-dependence of the brain organisation. In the current study we are investigating the role of the “visual” cortex of sighted and early blind people in reading from touch using the Braille system. First, using fMRI, we characterised brain responses to tactile word reading (experimental condition) and nonsense Braille (control condition) in congenitally blind (N = 18; age M = 34.4; SD = 7.5) and trained sighted (N = 26; age M = 23.1; SD = 3.4) subjects. Whole-brain comparisons revealed that tactile reading engaged the left inferior frontal gyrus (IFG) and ventral occipito-temporal cortex in both groups. However, reading meaningful Braille, when compared to the control condition, elicited activity in the early “visual” cortex selectively in the congenitally blind subjects. This enhanced V1 activity could not be explained by the higher tactile reading proficiency of blind subjects. Furthermore, psycho-physiological interaction analysis showed stronger functional connectivity between left IFG and V1 in the blind during the experimental condition, indicating possible reading-specific coupling between deprived visual cortex and language network. In the next stage of the project that we are currently carrying out, we are investigating temporal interactions between V1 and the visual word form area (VWFA). With the chronometric transcranial magnetic stimulation (TMS) which enables to causally trace the hierarchy between targeted brain regions, we are examining the information flow between low-level and higher-order visual areas during reading and speech processing in blind and sighted subjects. We plan to use 20 Hz repetitive TMS to temporarily disrupt neuronal processing in V1 and the VWFA. Pulses will be delivered in “early” (50-150 ms) and “late” (150-250 ms) time windows during lexical decision tasks performed aurally and tactually (blind subjects) or visually (sighted subjects). This experimental design allows us to trace linguistic processing in the visual cortex and its dependence on the sensory modality. TMS disruption during reading and speech processing observed first in VWFA and then in V1 could indicate that the deprived visual cortex performs linguistic computations occurring after orthographic analysis. Inversely, information flow from V1 to VWFA could support the view in which V1 retains its specialisation towards simple spatial processing of sound and touch, which is then followed by orthographic analysis occurring in the VWFA. In conclusion, with the combination of multiple state-of-the-art neuroimaging methods, the present project aims to investigate whether the blind visual cortex responds differently to (tactile) reading and speech processing. In conjunction with our previous findings, results of this study should contribute to a deeper understanding of the nature of the blind visual cortex in the context of currently discussed theoretical frameworks.

Topic Areas: Reading; Speech Perception

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Longitudinal Structural Plasticity of the Language Network by Second Language Learning *Sandbox Series*

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Introduction: Languages of the world strongly differ from one another in all dimensions (sound, lexicon, syntax, and orthography)(Evans and Levinson, 2009), and each language relies on a particular neural network adapted to its processing demands (Ge et al., 2015; Goucha, 2019; Paulesu et al., 2000). Similar to the specialization of the brain to the characteristics of the mother tongue, efficient processing of novel structures in adult foreign language learning was previously related to brain plasticity in various gray matter and white matter regions (Bialystok et al., 2012; Li et al., 2014; Qi and Legault, 2020). Here we analyzed the longitudinal structural changes of the white matter language connectome during adult second language learning in a large and well controlled cohort. Method: We recruited 60 healthy right-handed Arabic native speakers (mean age, 25.9 years; range, 19-34) for an intensive German course (5h/day, 5days/week) over a 6-months period. We acquired high spatial resolution diffusion MRI data from each participant at the beginning (time point 0: TP0), after 3 months (TP1), and after 6 months (TP2) of language learning. Using probabilistic tractography, we computed the structural network between all the language-related areas in both hemispheres. We first analyzed overall connectivity change (sum of all weighted connections in language network) by testing the brain lateralization at each time point in a paired t-test analysis. In a longitudinal analysis, we then tested the learning-induced change of the intra- and inter-hemispheric connectivity using a Linear Mixed Effects (LME) model with each time point as fixed effects. To localize the learning-induced connectivity change across each time point to specific connections and subnetworks, we used the Network-Based R-statistic (NBR) mixed-effects models (p-threshold = 0.01, K = 3000 permutations)(Zeus Gracia-Tabuenca et al., 2020). Results: The lateralization test showed leftward lateralization of the network for the initial and the middle timepoint (TP0: Left >> Right, t= 3.11, p= 0.003; TP1: Left > Right, t = 2.04, p= 0.046; TP2: Left ≯ Right, t = 1.79, p= 0.08). The longitudinal analysis in a LME model statistic showed a significant dynamic decreased inter-hemispheric connectivity during leaning with the strongest effect in the second half of the learning period (TP0-TP1: t = -1.1, p = 0.27 (n.s.)； TP1-TP2: t = -6.2, p = 1.4e-08， TP0-TP2: t= -8.1, p =1.2e-12). Finally, the NBR showed increased intra-hemispheric connectivity in sub-networks, including the bilateral parietal-temporal system and the right IFG mainly in the second half of the learning period. Additionally, the connectivity of sub-networks including connections of orbital IFG–aSTG, parahippocampal- lateral temporal lobe and inter-hemisphere were decreased. Conclusion: The present study showed a dynamic reorganization of multiple sub-networks during second language learning. During the initial learning period, the intra-hemispheric connectivity of phonological-semantic related sub-networks increased, while subnetworks related with lexical retrieval and long-term memory showed a decrease in connectivity. In addition, we found a crucial role of the right hemisphere in second language learning and reduced transcallosal connectivity between hemispheres related to a stronger intra-hemispheric specialization of both hemispheres.

Topic Areas: Multilingualism; Meaning: Lexical Semantics

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Semantic processing during the natural reading *Sandbox Series*

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Introduction: Through reading, we crack meaning out of the rich text. Event-Related Brain Potential (ERP) literature regards N400 as an index for semantic processing (Kutas and Federmeier, 2010). Kutas & Hillyard (1980) first characterized N400 as a negative potential between 200 and 600ms, peaking around 400ms, which was higher for semantic incongruent than congruent sentences. However, the classic N400 paradigm is not natural reading and parafoveal information is not available. Words from a sentence are presented one by one on the screen centre at a pace of around one word per second. Although N400 inspires the conceptualization of how meaning processing might unfold, its time course is strikingly slow regard the fast natural reading. So, how the meaning processing unfolds in the natural reading where parafoveal information is available? Methods: Participants will read 180 one-line sentences silently while eye movements and brain activities are recorded by an eye-tracker and MEG simultaneously. Every sentence is plausible and contains an unpredicted critical target word. Half of the target words make sentences semantic congruent, the other half incongruent. In our previous study (Pan, Frisson, and Jensen, 2021), Rapid Invisible Frequency Tagging (RIFT) has been shown to be a powerful tool to capture parafoveal processing during natural reading. Here we apply RIFT to flicker the critical target word by adding a patch underlie it. The luminance of this patch changes from black to white as a sinusoid at 60Hz, which is invisible on a grey background and will not interfere with reading. Tagging responses will be estimated as the coherence at 60Hz between tagging signal and brain activities. Coherence during the fixations of pre-target words reflects the previewing of flickering target words in the parafovea. We will also calculate the N400 difference between semantic congruent and incongruent conditions aligning with fixation onset to the target words. Results: We expect stronger 60Hz coherence for the fixations of pre-target words when followed by semantic incongruent compared with congruent target words. Besides, a classic semantic violation effect is expected for the fixations of target words: stronger N400 amplitude for semantic incongruent compared with congruent target words. We also expect that the pre-target coherence difference correlates positively with reading speed (estimated from congruent sentences only), but negatively with the N400 difference of the foveal target words. Conclusion: Semantic information can be extracted even before making saccades to that word. This semantic parafoveal processing facilitates reading performance. Therefore, rapid meaning processing unfolds to both foveal and parafoveal words in a distributed way during the natural reading.

Topic Areas: Reading; Methods

Slide Slam S14 Play Video View PDF

Agreement processing as a domain-general mechanism? An artificial grammar study *Sandbox Series*

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The domain-specificity or generality of core linguistic operations has been the object of extensive theoretical and experimental study. Support for the domain-general view comes from studies implementing different types of artificial grammar (AG) learning paradigms (see Siegelman et al., 2017), which suggest the presence of common mechanisms across domains (e.g., tracking of statistical regularities and sequential processing). We here present the design of a behavioral study aimed to further explore the role of domain-general mechanisms in language by focusing on agreement. Specifically, we plan to test how agreement rules are learned and identified in a visuo-spatial, shape-based AG. We capitalize on Basque agreement patterns, which prototypically show double agreement between verbs and both subjects and objects. Moreover, to better understand the impact of individual differences, we assess to what extent linguistic background (e.g., proficiency) is associated with AG performance. Spanish-Basque bilinguals (N=54) differing in their Basque proficiency will be tested on a visuo-spatial AG based on abstract geometrical shapes (combinations of circles, squares and triangles in different colors). Trials consist of sequences composed by 4 shapes mapped to grammatical functions (adverb, subject, object, and verb). Subject and object shapes fit the verb shape in a puzzle-like manner, mimicking the agreement relations established between verbs and both subjects and objects in Basque. Shapes' ordering in each sequence follows Basque word order (subject-object-verb), with the adverb shape occupying random pre-verbal positions. During training, participants will perform a self-paced task with correct trials, advancing each shape at their own pace by pressing the spacebar. In the test phase, the self-paced task will comprise correct trials, as well as incorrect ones displaying single instances of agreement (i.e., between verb and either subject or object shapes). An acceptability judgment (AJ) task will be performed after each test trial to evaluate whether the sequence followed the rules of the Basque-like AG. Similar self-paced reading and AJ tasks will be administered with Basque sentences containing both correct and incorrect number agreement relations. Response times (RTs) at final verb-shape position in training trials will show whether progressive learning of visuo-spatial agreement leads to faster RTs, possibly reflecting participants' prediction of the upcoming element. RTs at verb-shape position in test trials will evidence whether encountering an agreement violation increases RTs compared to agreement-correct trials, suggesting participants' learning of AG rules. Offline accuracy from the AJ will show whether participants successfully learned the Basque-like AG (i.e., accuracy above chance). Correlations will be run between (i) AG and Basque-sentence performance, and (ii) AG performance and Basque proficiency. If agreement relations are processed similarly across domains, we expect a positive correlation between Basque-like AG and Basque-sentence performance. In addition, if successful learning of the AG is associated with Basque proficiency, greater accuracy and faster RTs in the AG task should emerge as speakers' proficiency in Basque increases. The results of our study will provide a better understanding of the potential domain-general basis of core language operations like agreement and of the impact of individual-level differences.

Topic Areas: Syntax; Multilingualism

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Cortical signatures of the interaction between prosody and syntax during naturalistic language processing *Sandbox Series*

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Recent studies have shown promising results in using computational modeling approaches for pinpointing the neural signatures underlying the processing of linguistic hierarchy at different levels (semantics: Broderick, 2019; Huth, 2016; syntax: Pallier, 2010; Brennan, 2012; acoustics: Rutten, 2018; Santoro, 2017). However, the interaction across these levels is poorly understood. Our goal is to investigate if the encoding of syntactic information in the brain is modulated by prosodic cues carried by naturalistic speech signals. Crucially, the influence between prosody and syntax is reciprocal (Bennett & Elfner, 2019), thus, a computational model representing these two different levels can uncover if and how the neural processing of linguistic (i.e., syntactic) information is facilitated by their interaction. To investigate the interaction between prosodic and syntactic information in the brain, we are currently analyzing a previously published MEG dataset consisting of data from 11 subjects recorded while listening to continuous speech (Donhauser, 2020). The stimuli that were presented to the participants consisted of four TED talks extracted from the TEDLium Dataset (Rousseau, 2012). Two sets of features were extracted from the TED talks to characterize the time course of the prosodic and syntactic model (PS model). The prosodic features are composed of intonational and rhythmic information obtained from a spectral analysis of the speech signal. The syntactic features consist of both statistical and linguistic information present in the talks. More specifically, these consist of two subsets: (1) a subset representing the contextual predictability of part-of-speech (PoS) for each word of the TED talks, derived via the state-of-the-art transformer GTP-2 (Radford, 2019); (2) a subset describing the dependency structure of each of the TED talk sentences, characterized by the number of left-side connections of each word obtained from a transition-based dependency parser (Honnibal, 2015; Lopopolo, 2021). We are currently planning to evaluate the prosody-syntax interaction in two steps. First, a regularized linear regression between the source-localized brain activity and the sets of features of the PS model will be used to assess the amount of variance explained by the two sets of spaces. Secondly, a variance partition analysis will be used to determine not only the amount of unique information explained by syntactic and prosodic features in the brain but also their interaction. The ongoing project will allow a deeper understanding of how brain dynamics involved in the processing of prosodic cues carried by the spectrotemporal components of the speech signal interact with those involved in the processing of syntactic information carrying different levels of complexity. Importantly, we predict that the exhaustive modeling of these two feature spaces can uncover their interaction not only from a temporal perspective but also pinpoint the brain areas involved in making use of paralinguistic information to boost the processing of higher-level, abstract linguistic features, ultimately facilitating speech comprehension.

Topic Areas: Syntax; Prosody

Slide Slam S16 Play Video View PDF

Discrimination of homophone forms – morphology, phonology or both? *Sandbox Series*

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In fMRI studies of language processing, morphology and phonology are mostly studied as two separate phenomena. Conditions with morphological anomalies (e.g. anomalously inflected verbs) are often contrasted with conditions with phonological anomalies (e.g. pseudohomophone spelling errors). This strand of research has shown distinct patterns for the two types of anomalies. Reading morphological anomalies is associated with increased activation of left inferior frontal gyrus (Carreiras et al. 2010; Carrieras et al. 2015), while phonological anomalies also tend to engage auditory areas (e.g. Newman & Joanisse 2011). In naturally occurring texts, the distinction between phonological and morphological anomalies is not that clearcut. In written Danish, the infinitive and the present tense of verbs are frequently confused. For verb stems with final -r, the infinitive and the present tense form are homophone – for other verb stems there is an audible difference between forms. For example there is an audible difference for overveje/overvejer ('consider/considers'), but not for vurdere/vurderer ('evaluate/evaluates')In our fMRI study we investigated whether the processing of verbal inflection in Danish involves both morphological and phonological processes. Twenty-eight Danish participants (age 20-31) read 128 short stories while they performed a semantic/pragmatic coherence judgment task in the scanner. The stimuli sentences contained a critical verb presented in one of the four conditions: 1. Anomaly with homophones: Han må vurderer situationen (English: 'He must evaluates the situation') 2. Anomaly with non-homophones: Han må overvejer situationen (English:'He must considers the situation') 3. Baseline for homophones: Han må vurdere situationen (English: 'He must evaluate the situation') 4. Baseline for non-homophones: Han må overveje situationen (English: 'He must consider the situation') Functional images were acquired in an EPI sequence on a Siemens Magnetom Trio 3-T MR scanner with a 32-channel head coil. The acquisition specifications were the following: TR = 1340 ms, TE = 29.6 ms, flip angle = 75°, voxel size = 1.8 x 1.8 x 1.8 mm. FWE corrected ($p < 0.05$) whole brain analysis showed no effect of grammar anomaly, no effect of homophony and no interaction. Four planned ROI analyses were conducted for: left IFG, primary and secondary auditory cortices, VWFA and left STG/MTG. The left pIFG, VWFA and pSTG were more activated in the non-homophone condition, compared to the homophone one. No other main effects or interactions were observed. In the coherence judgment task, there was lower accuracy for stories with anomalous inflection than those with correct inflection. Accuracy was also lower for non-homophone conditions compared to homophone conditions. Both behavioural and fMRI findings suggest that the non-homophone forms require extra processing effort, engaging extra activation in areas in the brain that are known for being involved in morphological processing (pIFG), phonological processing (pSTG) and written word recognition (VWFA). These results are an indication that processing of verbal inflections may both involve morphological and phonological processing.

Topic Areas: Morphology; Phonology and Phonological Working Memory

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Sleep Dependent Consolidation in Language Learning among Adults with and without Dyslexia – A Sandbox Submission *Sandbox Series*

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Background: Dyslexia is a universal neurodevelopmental disorder affecting ~7% of the population. It is characterized by slow, error-prone, reading and broader language-related deficits. Individuals with dyslexia (IDDs) have a smaller vocabulary and difficulty learning language regularities in some tasks. This study focuses on the role of sleep in the consolidation of learning of linguistic rules and novel vocabulary among adults with and without dyslexia. Sleep plays an active role in the consolidation of newly learned linguistic information in typically developing individuals, but the link between sleep and language learning in dyslexia is understudied. The role of sleep in consolidation in dyslexia has only been examined in a small number of developmental studies, and no studies were conducted with adults. Thus, the goals of the proposed study are to examine learning and consolidation of new vocabulary and new linguistic rules in adults with dyslexia, to examine sleep patterns of adults with dyslexia, and to examine how language consolidation is affected by sleep architecture and properties among adults with and without dyslexia. Methods: Fifty adults, half of whom will have a diagnosis of dyslexia, will participate in the study. Screening tests will be performed to collect standardized measures of reading ability, phonological and morphological abilities, and working memory. The artificial language is adapted from previous studies, which have shown evidence for sleep-dependent facilitation of learning of new words and linguistic regularities. We examine item specific learning, and also measure generalization of regularities to untrained items. The procedure includes an evening training followed by polysomnography acquired during the night in a sleep lab. Additional tests are administered 12 hrs., 36 hrs., and one week after training to assess offline consolidation. Sleep stages will be scored and other sleep measures will be computed: number of sleep cycles, power spectral density, amount of slow wave sleep, k-complexes, spindle count and density, and a coherence measure between spindle density and slow wave activity. First, sleep characteristics of IDDs will be compared to those of non-IDDs. Additionally, the correlation of these sleep measures with offline consolidation on the experimental task, and with standardized measures of phonological and morphological abilities will be examined.

Topic Areas: Morphology; Disorders: Developmental

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Undoable: computing hierarchical morphological structures in Aphasia *Sandbox Series*

Kyan Salehi[1], Caitlyn Antal[1], Alexa Ray Falcone[1], Laura Pissani[1], Roberto G. de Almeida[1]; [1]Concordia University

INTRODUCTION Linguistic productivity relies on the ability to compute morphologically complex hierarchical structures. This ability is mostly determined by accessing knowledge of selectional restrictions of roots and affixes. For instance, in a word such as “unsinkable” the prefix “un-“ attaches to the complex adjective sinkable, not to the verb “sink” (thus, ruling out “unsink”). Conversely, in the case of “unlockable”, both morphological structures can be computed: [un[lockable]] “not able to be locked” or [[unlock]able] “able to be unlocked”. As such, the correct parsing of these trimorphemic structures directly determines the derived meaning. Few experimental studies have investigated the parsing and interpretation of these types of words in isolation and in context (de Almeida & Libben, 2005; Libben, 2003; Libben, 2006; Pollatsek, Drieghe, Stockall, & de Almeida, 2010). Results have shown either right- or left-branching preference, with factors such as context and frequency affecting later rather than initial stages of analysis. We investigated morphological parsing in individuals with aphasia to understand (a) whether there is a default parsing strategy, (b) how sentential-semantic context influences parsing preferences, and (c) the breakdown of morpho-semantic processing across different clinical groups of aphasia. METHOD Participants were 12 individuals with aphasia (3 fluent [FL], 2 mixed [MX], 2 mixed but predominantly non-fluent [MN], 5 non-fluent [NF]). Controls were 30 healthy individuals matched to the clinical groups in age, sex, and education. All participants were native speakers of English. Stimuli consisted of 48 sentences containing ambiguous trimorphemic words (e.g., unlockable), with 24 biasing towards the left-branching and 24 towards the right-branching analysis of the trimorphemic word (e.g., ‘When the zookeeper went to unlock/lock the cage, he found it was unlockable’). In addition, materials included 24 sentences containing left-branching words ([[refill]able]) and 24 sentences containing right-branching words ([un[sinkable]]). These sentences were divided into two booklets, with each participant completing one booklet. Participants (a) rated how good each sentence was on a 5-point scale (Rating task: 1-bad, 5-good), and (b) indicated, by drawing a vertical line, where a separation could be made on target words (Parsing task) taken from each sentence and presented after the rating scale. RESULTS AND DISCUSSION Correct parsing was analyzed by items, considering word type (right-branching ambiguous, left-branching ambiguous, right-branching unambiguous, left-branching unambiguous) and group (controls, FL, MX, MN, NF), with repeated measures on the second factor. A cut before the suffix in the case of left-branching words ([[unlock]able], [[refill]able]) and a cut after the prefix for right-branching words ([un[lockable]], [un[sinkable]]) were considered correct. Results showed a main effect of word type and an interaction. Both the MX and the NF groups differed significantly from the control group across all word types, with the exception of a marginal difference for the MX group on right-branching words. Results are consistent with online experiments (de Almeida & Libben, 2005; Pollatsek et al., 2010) suggesting that the right-branching parse is preferred early in morphological analysis regardless of context. Notably, the NF group showed the inverse effect, indicating that the morphological parser can be affected in non-fluent aphasia.

Topic Areas: Morphology; Disorders: Acquired

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Distinct aspects of phrasal production are associated with distinct lesion correlates in chronic post-stroke aphasia *Sandbox Series*

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INTRODUCTION We used the Morphosyntactic Generation Task (MorGen) (Stockbridge, Matchin, et al., 2021; Stockbridge, Walker, et al., 2021), to assess the lesion correlates of different aspects of phrasal production in people with chronic aphasia. The MorGen is designed to elicit two-word noun phrases involving different modifiers: numeral quantifiers (one vs. two), color adjectives (red vs. blue), size adjectives (big vs. small) and inflectional morphology (plural -s vs. null inflection, possessive -s; Figure 1). Here we report lesion-symptom mapping analyses in chronic post-stroke aphasia, in order to ascertain whether impaired production of features are associated with distinct lesion correlates. Prior work in progressive aphasia found that size features were not a strong basis of impairment regardless of variant (Stockbridge, Matchin, et al., 2021), so only plural and possessive inflectional marking, color, and number were examined. ***METHODS*** Twenty-six people with chronic post-stroke aphasia were assessed on the MorGen. The MorGen presents two simultaneous images in each trial, which contrast based on one feature (number, color, size, possession). Subjects are asked to describe the target image using two words. We assessed inflectional morphology by averaging across performance on plural and possessive -s and assessed color and number separately. Subjects' lesions were manually drawn on their MRI scans and subsequently warped to MNI space (Fridriksson et al., 2018). We tested three regions of interest (ROIs): posterior temporal lobe (JHU atlas, posterior STG and MTG), Broca's area (JHU atlas, pars opercularis and pars triangularis), and anterior arcuate fasciculus (Catani atlas, overlap with posterior temporal lobe ROI removed). We calculated the percent damage to each ROI for each subject and then performed regression analyses in NiiStat (https://www.nitrc.org/projects/niistat/) to assess the relationship between performance on each measure and damage to each ROI. **RESULTS** Performance on the three measures of interest dissociated from each other. Performance deficits were associated with the following lesion correlates ($p < 0.05$). Color adjectives: damage to arcuate fasciculus ($Z = -2.33$) and posterior temporal lobe ($Z = -2.30$). Numeral quantifiers: damage to Broca's area ($Z = -2.00$). Inflectional morphology: damage to arcuate fasciculus ($Z = -2.81$) and Broca's area ($Z = -1.77$). ***CONCLUSIONS*** Color adjective deficits involved posterior regions, similar to those described previously for deficits on picture naming tasks with noun targets (Baldo et al., 2013; DeLeon et al., 2007; Fridriksson et al., 2018). Deficits in inflectional morphology were primarily associated with damage to arcuate fasciculus and, to a lesser extent, Broca's area. This is consistent with the need to coordinate posterior temporal and inferior frontal regions with each other to select the correct inflectional form given the structural context (Matchin & Hickok, 2020). Finally, deficits on numeral quantifiers primarily implicated damage to Broca's area, which is consistent with a role for this region in retrieving functional elements. In sum, production of different morphemes requires overlapping but distinct brain systems.

Topic Areas: Morphology; Language Production

Slide Slam S20 Play Video View PDF

Family or foe: the morphological kinship between words *Sandbox Series*

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Lexical access allows the immediate understanding and production of words online. Despite being a basic linguistic computation, there is a lot of heated theoretical dispute in this area. For example, literature presents competing views regarding how semantically opaque words are accessed and stored. This study will present an empirical research whose results shed light on: i) the way we access transparent and semantically opaque words, that is, if we activate whole words (Hay, Baayen, 2005) or if we assemble them by their morphemes (Stockall, Marantz, 2006); and ii) the method of representing words in the mind, that is, if words bearing a semantic relationship between them would be linked and words having a morphological relationship with each other would also be linked, but by a different process than the semantic one (Garcia, 2009; Dominguez, Vega, Barber, 2004). The Distributed Morphology (MD – Halle, Marantz, 1993) theory suggests that there are different lexical approaches, originated from psychologically different processes. However, how would the processing of words that bear a morphological relationship occur? Note that some of these words once had a semantic relation, but under the synchronous perspective have lost it. This is the case in “liquidação” (sale - meaning ‘with a cheap price’) and “líquido” (liquid), in Brazilian Portuguese. “Liquidação” (sale) derives diachronically from “líquido” (liquid), but nowadays Brazilian speakers seem to ignore this semantic relationship. This very specific type of morphological and semantic relationship between words has never been tested before in Brazilian Portuguese. In order to evaluate MD predictions, we will run a priming test with a lexical decision judgment (word/non-word). We will compare pairs of synchronically semantically unrelated (but morphologically linked) words -like “líquido”(liquid)/“liquidação”(sale) with pairs that maintain transparent compositional relationship -like “líquido”(líquido)/“liquidificar”(liquefy)- and, still, with pairs that maintain only semantic (and not morphological) relationship -like “líquido”(liquid)/“aquoso”(aqueous). For each of these three conditions, we selected stimuli with two different sizes/morphologic layers: for instance, “líquido-liquidificar”(liquid-liquefy), presented above, stand for the short condition of the compositional relationship, while “líquido-liquidificação”(liquid-liquefaction) stand for the long one. The results of a first behavioral pilot test confirm the MD hypothesis, evidencing i) a decomposicional course during processing, even for this kind of semantically opaque words; ii) new entries for words as “liquidificação” (sale) in the mental lexicon; and iii) different psychological processes for the morphologic and semantic routes: linguistic composition for the former and joint memory for the latter. Due to pandemic sanitary conditions, we have not yet been able to test the neurophysiological correlates to this computation (Bozic et at., 2007; Lavric, Clapp, Rastle, 2007; Moris et al., 2007; Petterson, Nestor, Rogers, 2007; Pylkkänen, 2019). As soon as it is possible, we will run an EGG test with the same design. We expect to find wider ERP amplitudes for the semantically opaque conditions and different latencies for each of the two-size-stimuli in morphological conditions (for both transparent and opaque ones) but not in the semantic-only one. These findings would ratify our conclusions for the pilot test.

Topic Areas: Morphology; Meaning: Combinatorial Semantics

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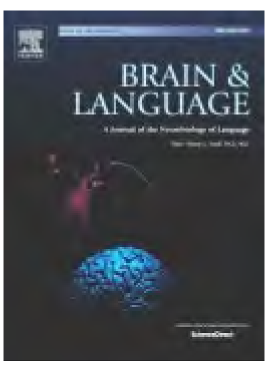

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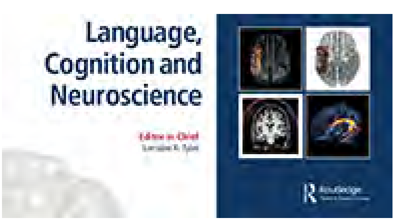

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