

October 15-16 | 09



NLC 2009 Scientific Program

The Neurobiology of Language Conference
Marriott Downtown Hotel,
540 North Michigan Avenue
Chicago, Illinois, US.

Table of contents

General Schedule	4
Keynote Lectures	5
1. Recent Insights Into The Anatomical Pathways For Language	5
2. Neuronal Oscillations as Instruments of Brain Operation and Perception	6
3. What can Brain Imaging Tell us About Developmental Disorders of Speech and Language?	6
4. Building Bridges Between Genes, Brains and Language	7
Panel Discussions	9
Panel Discussion A: The Battle for Broca’s Area: Syntax, Semantics, and/or Beyond	9
Panel Discussion B: Motor Contribution to Speech Perception: Essential or Ancillary?	11
Slide Sessions	13
Slide Session A	13
Slide Session B.....	16
Poster Sessions	19
Poster Session A.....	19
<i>Comprehension</i>	19
<i>Acquisition and Learning</i>	34
<i>Multilingualism</i>	40
<i>Reading and Writing</i>	46
<i>Syntax</i>	60
Poster Session B	68
<i>Speech perception</i>	68
<i>Speech production</i>	81
<i>Motor behavior and language</i>	91
<i>Prosody</i>	100
<i>Cognitive and Executive Functions</i>	104
<i>Aging, plasticity and brain injury</i>	110
Conference Registration	119
Conference Venue	120
Accommodations	121
Conference Organization	123
Author Index	125

General Schedule

Schedule for Thursday, October 15 2009

Time	Event	Room
7:00 – 8:45 am	Breakfast and registration	State Room
8:45 – 9:00 am	Opening Remarks	Avenue Ballroom
9:00 – 10:00 am	Keynote Lecture: Michael Petrides (<i>McGill University, Canada</i>)	Avenue Ballroom
10:00 - 10:15 am	Coffee Break	State Room
10:15 am - 12:15 pm	Panel Discussion: The Battle for Broca's area (Featuring Yosef Grodzinsky and Peter Hagoort)	Avenue Ballroom
12:15 – 1:45 pm	Lunch Break	
1:45 – 2:45 pm	Keynote Lecture: Charles Schroeder (<i>Columbia University College of Physicians and Surgeons, Nathan Kline Institute for Psychiatric Research, USA</i>)	Avenue Ballroom
2:45 - 4:15 pm	Slide session A	Avenue Ballroom
4:15 - 6:45 pm	Coffee break and Poster session A Comprehension, Acquisition and Learning, Multilingualism, Reading and Writing, Syntax	Halsted Room
6:15- 7:00 pm	Business Meeting	Avenue Ballroom
7:00 – 9:00 pm	Wine and cheese reception	Halsted Room

Schedule for Friday, October 16 2009

Time	Event	Room
7:00 – 8:45 am	Breakfast and registration	State Room
8:45 - 9:00 am	Opening Remarks	Avenue Ballroom
9:00 - 10:00 am	Keynote Lecture: Kate Watkins (<i>University of Oxford, UK</i>)	Avenue Ballroom
10:00 - 10:15 am	Coffee Break	State Room
10:15 am - 12:15 pm	Panel Discussion: Motor Contribution to Speech Perception: Essential or Ancillary? (Featuring Luciano Fadiga and Gregory Hickok)	Avenue Ballroom
12:15 – 1:45 pm	Lunch Break	
1:45 – 2:45 pm	Keynote Lecture: Simon Fisher (<i>University of Oxford, UK</i>)	Avenue Ballroom
2:45 - 4:15 pm	Slide session B	Avenue Ballroom
4:15 - 6:45 pm	Coffee Break and Poster Session B Speech perception, Speech production, Prosody, Motor behavior and language, Cognitive and executive functions, Aging, plasticity and brain injury	Halsted Room
6:30 - 6:45 pm	Closing Remarks	Avenue Ballroom

Keynote Lectures

I. Recent Insights Into The Anatomical Pathways For Language

Thursday, October 15 2009, 9:00 - 10:00 a.m., Avenue Ballroom

Chair: Ana Solodkin (The University of Chicago, U.S.)



Michael Petrides holds a James McGill Research Chair and is the Director of the Neuropsychology and Cognitive Neuroscience Unit, Montreal Neurological Institute, McGill University, where he is a professor in the Departments of Neurology and Neurosurgery and the Department of Psychology. He obtained his Bachelors and Masters degrees from the University of London and a Ph.D. in Behavioral Neuroscience from the University of Cambridge. He was a research fellow at Harvard Medical School before moving to McGill University. His research focuses on the cognitive function and the neuroanatomy of the prefrontal cortex. His experimental studies of the cognitive deficits that follow highly selective lesions to particular architectonic areas of the prefrontal cortex of the monkey and parallel studies on patients with brain damage, as well as his functional activation studies on normal human subjects with functional magnetic resonance imaging have provided influential new conceptualizations of the anatomical and functional organization of the primate prefrontal cortex. He has published cytoarchitectonic maps of the human and macaque monkey prefrontal cortex, which are based on comparative studies in which the same criteria are used to define areas in the two primate species. These studies have helped resolve major controversies and inconsistencies found in the classic maps and are now used worldwide to facilitate the transfer of information from basic anatomical and physiological studies on nonhuman primates to the human brain and vice versa. He received a James S. McDonnell 21st Century Scientist Award: Bridging Brain, Mind and Behavior (2001), was awarded a Killam Scholarship (2007) to recognize exceptional research accomplishments, and was elected Member of the American Academy of Arts and Sciences (2007).

Abstract: Two distinct architectonic areas, namely dysgranular area 44 and granular area 45, constitute the classical anterior language zone (Broca's region). Although traditional views of how the posterior ventrolateral frontal region (Broca's region) of the human brain is connected with posterior cortical areas has been dominated by the simple scheme of an arcuate fasciculus that links the posterior with the anterior language zones, experimental anatomical studies that we conducted in the 1980s in the macaque monkey showed that, even in the non-linguistic nonhuman primate brain, the connections were much richer: a massive pathway via two branches of the superior longitudinal fasciculus linked the inferior parietal lobule with the ventrolateral frontal region and another massive pathway via the extreme capsule linked the mid-lateral temporal lobe with the ventrolateral frontal region (Petrides and Pandya, 1984, 1988, J. Comp. Neurol.). More recently, diffusion tensor imaging (DTI) studies have shown that these pathways also exist in the human brain. DTI, however, cannot establish details of pathways, such as precise origin and termination within particular cortical areas. We have now established by means of architectonic analysis the precursors of Broca's region (areas 44 and 45) in the macaque monkey ventrolateral frontal cortex which has enabled us to use experimental anatomical methodology to examine the precise origins within the multiple parietal and temporal cortical areas of axonal pathways that terminate within architectonic areas 44 and 45. These recent anatomical findings demonstrate a dorsal stream of fibers via the superior longitudinal/arcuate fasciculi that can be further subdivided into a rostral and a caudal component bringing parietal and caudal temporal information to areas 44 and 45 and an independent ventral temporo-frontal system via the extreme capsule fasciculus that targets predominantly the prefrontal cortical area 45 and the adjacent area 47/12. It is likely that these pathways, which are additional to the arcuate fasciculus (traditionally assumed to be the main language pathway), play major roles in language processing in the human brain and provide an anatomical basis for much more diversified theoretical models of language processing.

2. Neuronal Oscillations as Instruments of Brain Operation and Perception

Thursday, October 15 2009, 1:45 - 2:45 p.m., Avenue Ballroom
Chair: David Poeppel (New York University, U.S)



Charles Schroeder is a professor at the Department of Psychiatry, Columbia University College of Physicians and Surgeons in New York, and a research scientist at the Nathan Kline Institute for Psychiatric Research, Orangeburg, New York. He obtained a B.A. in Psychology from Ohio State University, Columbus, Ohio, a M.A. and a Ph.D. in Psychology from the University of North Carolina, after which he was a post-doctoral fellow at the Department of Neuroscience, Albert Einstein College of Medicine. His research program aims to define the neural circuits, cellular processes and temporal dynamics of sensory perception and other cognitive processes such as attention, discrimination and learning. The work requires integration of monkey and human studies and is made possible by recent advances in electrode, computing and brain imaging technologies. The work also requires a constant exchange between empirical and computational/ modeling investigations. The results of the monkey and human studies are directly interrelated by

using the same neural measurements and focusing on the same brain operations. Monkeys are then studied further using more invasive techniques in order to directly define the neural mechanisms. Invasive techniques include single cell and cell ensemble electrophysiology, often with pharmacologic manipulations, and using both acutely and chronically positioned multielectrode arrays. Noninvasive techniques include ERP recording, along with both anatomical and functional MRI.

Abstract: Neuroelectric oscillations reflect rhythmic shifting of neuronal ensembles between high and low excitability states. Recent findings indicate that neuronal oscillations both enable and constrain the brain's processing of sensory inputs, as well as its generation of motor outputs. I will discuss recent findings concerning the way the brain uses oscillations to process, select, and integrate inputs, and also the way that motor sampling routines may help to organize and control oscillatory mechanisms of sensory input processing. The discussion will range across several sensory modalities, and will end with a focus on selective attention's manipulation of low frequency oscillatory phase as a mechanism of sensory selection in primate VI. I will also discuss a conceptual framework that can help relate our understanding of brain dynamics to the study of perception.

3. What can Brain Imaging Tell us About Developmental Disorders of Speech and Language?

Friday, October 16 2009, 9:00 - 10:00 a.m., Avenue Ballroom
Chair: Vincent L. Gracco (McGill University, Canada, Haskins Laboratory, U.S.)



Kate Watkins is a University Lecturer at the Department of Experimental Psychology and at the Centre for Functional MRI of the Brain (FMRIB), University of Oxford, UK, and a Tutorial fellow at St Anne's College, University of Oxford. She obtained a Bachelor degree from the University of Cambridge, a Master degree in Neurological Sciences from University College London and a Ph.D. in Cognitive Neuroscience at the Institute of Child Health, University College London in 1999, after which she was post-doctoral scholar at the Cognitive Neuroscience Unit of the Montreal Neurological Institute, and a post-doctoral research fellow at the Centre for Functional MRI of Brain, University of Oxford. Her research interests are in normal and abnormal brain development, specifically in the domain of speech and language. She studies populations with speech and language disorders such as specific language disorders (SLI) and developmental stuttering using structural and functional MRI. She also uses transcranial magnetic stimulation (TMS) in

normal healthy adults to examine the interactions between motor and auditory areas during speech processing. She has also looked at normal patterns of brain asymmetry and brain development during adolescence in healthy populations using MRI.

Abstract: In children with developmental disorders of speech and language, examination of MRI brain scans of affected individuals fails to reveal visible structural abnormalities. Instead, the suspected genetic aetiology of these disorders is thought to result in abnormalities detectable only by computational morphometric analyses of high-resolution datasets. Such abnormalities are likely a product of differences in neuronal number, size, synaptic density, connectivity and myelination, amongst others. Identification of brain regions with abnormal structure can inform our understanding of the underlying deficit. This was demonstrated in the first of our studies using voxel-based morphometry to explore the structural correlates of the verbal dyspraxia associated with an abnormality in the FOXP2 gene. Bilateral reduction in the volume of gray matter in the caudate nucleus in affected members of the KE family led us to conclude that the impairment lay at the level of learning or sequencing articulation patterns (Watkins et al., 2002). More recently, we have combined analyses of brain structure and function to examine the neural correlates of two other developmental disorders of speech and language, namely, developmental stuttering and specific language impairment (SLI; Watkins et al., 2009). In developmental stuttering, micro-structural white matter abnormalities were revealed using diffusion-tensor imaging. This disruption of white matter organisation was found to relate to abnormal functional activity measured with functional MRI in the frontal opercular cortex during overt speech in people who stutter (Watkins et al., 2008). In SLI, we have also found both structural and functional abnormalities in the left frontal opercular cortex. Here, in comparison with control children, there is significantly reduced activity during a language task in children with SLI and significantly greater amounts of grey matter. On the other hand, in posterior superior temporal sulcus, children with SLI show lower grey matter volume and reduced activity. Children with SLI and their unaffected siblings also exhibit significantly less grey matter than control children in the caudate nucleus bilaterally - a finding strikingly similar to that seen in the affected members of the KE family. The role of the caudate nucleus and of cortico-striatal-thalamo-cortical loops in speech and language disorders remains to be elucidated though it clearly implicates an underlying motoric deficit. In developmental stuttering, however, we have failed to observe any structural abnormalities of the caudate nucleus, despite strong evidence to suggest abnormal function of the basal ganglia in this disorder. Taken together, the results of these studies highlight the importance of understanding the relationship between brain structure and function, particularly in abnormal development. Several fundamental questions remain to be addressed with further study, including the following: (i) Are the structural abnormalities a cause or a consequence of the disorder? (ii) What is the relationship between measures of brain structure and function and behavioural measures? (iii) How do the abnormal amounts of tissue in a cortical area affect the measurement of functional signals?

Watkins KE, Vargha-Khadem F, Ashburner J, Passingham RE, Friston KJ, Connelly A, Frackowiak RSJ, Mishkin M & Gadian DG (2002) MRI analysis of an inherited speech and language disorder: structural brain abnormalities. *Brain* 125: 465-478. Watkins KE, Smith SM, Davis S, Howell P (2008) Structural and functional abnormalities of the motor system in developmental stuttering. *Brain* 131: 50-59. Watkins KE, Badcock NA, Hardiman MJ, Barry JG, Bishop DVM (2009) What's the matter with gray matter? Neurobiological risk factors for specific language impairment. Society for Neuroscience Abstract, Chicago, 2009.

4. Building Bridges Between Genes, Brains and Language

Friday, October 16 2009, 1:45 - 2:45 p.m., Avenue Ballroom

Chair: Kunioshi Sakai (Tokyo University, Japan)



Simon Fisher is a Royal Society Research Fellow and Reader in Molecular Neuroscience at the Wellcome Trust Centre for Human Genetics (WTCHG), University of Oxford, UK, where he pioneers investigations into molecular mechanisms underlying speech and language. Simon obtained his Natural Sciences degree at Trinity Hall, Cambridge University, UK, specialising in Genetics. From 1991-1995, he carried out doctoral research at the Genetics Unit of the Biochemistry Department, Oxford University, and isolated a gene causing an inherited kidney-stone disorder. From 1996-2002, Simon was a senior post-doctoral scientist in Prof. Anthony Monaco's group at the WTCHG, where he led research teams searching for genomic variants that are implicated in childhood learning disabilities. During this time he identified FOXP2, the first case of a gene mutated in speech and language impairment. In 2002, Simon became head of his

own laboratory, which uses state-of-the-art methods to uncover how language-related genes influence the brain at multiple levels. Simon is also the Isobel Laing Fellow in Biomedical Sciences at Oriel College, where he teaches Biochemistry and Medical Genetics. He is author of over 60 journal articles, including high-impact peer-reviewed research in *Nature*, *Nature Genetics*, *New England Journal of Medicine*, and *Cell*, and is frequently invited to talk at leading international conferences across a diverse range of fields. His research benefits from a strong interdisciplinary remit, integrating data from genetics and genomics, psychology, neuroscience, developmental biology and evolutionary anthropology. In 2008 Simon was awarded the prestigious Francis Crick Prize Lecture by the Royal Society.

Abstract: Genes that are implicated in neurodevelopmental disorders can provide novel insights into neural mechanisms contributing to human spoken language. We previously discovered an interesting gene known as FOXP2. People with mutations that disrupt FOXP2 have problems mastering sequences of co-ordinated mouth movements needed for fluent speech, accompanied by expressive and receptive language impairments affecting spoken and written modalities. The FOXP2 gene encodes a type of regulatory protein which acts to switch on and off other genes. It is evolutionarily ancient, present in similar form in diverse vertebrate species, where it helps regulate the development and function of corresponding subpopulations of neurons. Analyses of molecular evolution in primates indicate that FOXP2 protein sequence underwent accelerated change on the human lineage after splitting from the chimpanzee, indicating that its role(s) may have been modified in our ancestors. Nevertheless, it is emphasised that FOXP2 should not be viewed as the mythical “gene for speech” or “gene for language”, but instead as one piece of a complex puzzle involving multiple factors. My talk will describe how FOXP2 can be used as a unique window into key neurogenetic pathways. To this end, researchers are exploiting a wide range of systems, from neuronal models, mutant mice and songbirds, to humans themselves. For example, state-of-the-art genomic techniques are being employed to identify genes that FOXP2 regulates in the human brain (its downstream targets). Intriguingly, it appears that some of these targets are also themselves implicated in language-related disorders. Studies of FOXP2 in animal models point to potential roles in neural plasticity; dysfunction of the gene leads to abnormal synaptic plasticity and impaired motor-skill learning in mice, and yields inaccurate and incomplete vocal imitation during song learning in zebra finches. Overall, this work demonstrates how we can begin to bridge gaps between molecules, neurons and the brain, helping us to build more sophisticated models of the relationships between genes, speech and language. Finally, the FOXP2 story shows how an appreciation of the language of genetics (what genes actually are and what they can and cannot do) is needed to constrain discussions regarding genetics of language.

Panel Discussions

Panel Discussion A: The Battle for Broca's Area: Syntax, Semantics, and/or Beyond

Thursday, October 15 2009, 10:15 a.m. - 12:15 p.m., Avenue Ballroom

Speakers: Yosef Grodzinsky and Peter Hagoort.

Moderators: Sharon Thompson-Schill (University of Pennsylvania, US) and Jeffrey Binder (Medical College of Wisconsin, US)

Intro: Since the pioneering work of nineteenth-century French neurosurgeon Pierre-Paul Broca, conflicting ideas have appeared on the subject of the role(s) of the posterior two-thirds of the left inferior frontal gyrus - the so-called Broca's area - in speech and language. Once believed to be involved in the articulation of speech, this intriguing, probably multifaceted brain region has been attributed a number of linguistic and non-linguistic functions, including syntactic processing, working memory, response selection, and semantic processing, but its role in language neurobiology is still at the core of scientific debate. This panel discussion will feature short talks by two researchers at the forefront of this debate, Dr. Yosef Grodzinsky and Dr. Peter Hagoort. The talks will be followed by a discussion among the panelists and the audience.

The panelists



Yosef Grodzinsky is Professor and Canada Research Chair in Neurolinguistics at the Department of Linguistics, at McGill University, where he is also an Associate Member of the Department of Neurology/Neurosurgery. He is also an adjunct Professor at the Department of Speech, Language and Hearing Science at the San Diego State University. He obtained a B.Sc. at The Hebrew University of Jerusalem in 1981 and a Ph.D. at the Brandeis University in 1985, under the supervision of Noam Chomsky, Merrill Garrett, and Edgar Zurif, after which he was a post-doctoral fellow at Center for Cognitive Science, MIT. His research interests include syntax, semantics, aphasic syndromes, and functional neuroimaging. In 2007 he received the Humboldt Senior Researcher Award, which enhanced his collaboration with the Forschungszentrum Jülich and the Leipzig MPI. His current research program focuses on the development of brain maps for syntax and semantics through fMRI studies of syntax and semantics in health and in focal and diffuse brain disease, which he conducts with his research partners in Montreal, Jülich, San Diego, and Leipzig.



Peter Hagoort is Professor of Cognitive Neuroscience at the Radboud University Nijmegen, director of the Donders Institute for Cognition, Brain and Behaviour, Centre for Cognitive Neuroimaging and director of the Max Planck Institute for Psycholinguistics. At the Centre for Cognitive Neuroimaging he is the leader of the research group Neurocognition of Language. This group researches the way complex language skills such as reading, listening and speaking are fixed in the human brain. This research has resulted in a large number of publications in leading journals such as Science and PNAS. For his scientific work Hagoort received the Hendrik Muller Prize of the Netherlands Academy for Art and Sciences (KNAW) in 2002. In 2004 he was appointed Companion of the Order of the Dutch Lion. He is also a member of the KNAW. In 2005 he was awarded the prestigious Spinoza prize for his excellent research and the outstanding performance in building up the Donders Centre for Cognitive Neuroimaging.

The abstracts

Grodzinsky

What do we hope to discover when we study neurolinguistics? At a minimum, we seek to identify regularities in the relationship between language structure (and processes that make use of it in linguistic communication) and brain structure (at all levels). This mapping project has been around at least since Wernicke superimposed pieces of linguistic ability onto pieces of neural tissue. He carved language into modalities, and the linguistic brain into big chunks. The result was the celebrated Wernicke/Lichtheim/Geschwind diagram, an example of which Andrea Santi and I used in the TICS paper that engendered the current debate. Standing on the shoulders of these giants, we now try to refine the maps and explore new vistas. Our tools – new imaging and anatomical technologies, and new linguistic and cognitive technologies – open the door to better neurolinguistic maps. Indeed, neurolinguistics has come of age. Organizational principles of the linguistic brain can be formulated, and discovery procedures for relevant evidence established. Much current work assumes (whether implicitly or explicitly) the following: Organizational principles of the linguistic brain:

1. Formal individuation and localization: major linguistic operations are neurologically individuated and localized.
2. Anatomical alignment: the neurological representation of formal linguistic operations aligns with anatomical borders.

These principles govern our current blueprint of a neurolinguistic map. They follow the spirit of the traditional neurological view in that they superimpose pieces of linguistic ability onto pieces of neurology. Yet they depart from this tradition in the units of analysis and the types of empirical evidence they use: Wernicke superimposed roughly sketched lesions onto gross anatomy, whereas we coregister precisely segmented lesions, and activation peaks and clusters with cytoarchitectonic probability maps; he had a naïve theory of language, which we top up with a refined formal linguistic perspective; his experimental methods centered around informal bedside interviews, while our modern controlled experimental methods (e.g., parametric designs) produce replicable results. In our TICS paper, Santi and I showed how current thought and technology lead to maps at a high cognitive, linguistic, and anatomical resolution, which we hoped would teach us a lesson that goes beyond Broca's region. In my talk, I will briefly review some of our arguments. I will also discuss other important developments. As evidence has accumulated, it has become increasingly clear that another organizational principle needs articulation:

3. Modular multi-functionality: there is (at least some) anatomical overlap between structured linguistic brain maps and other neurocognitive maps.

Recent results indicate that the language regions specialize in different things, and that these specializations overlap to some degree. Broca's region, for one, seems to specialize in Movement relations when syntax is at issue, but also, in

Hagoort

There is a certain tendency in neurolinguistic circles to assign a sacrosanct status to Broca's area as the pinnacle of the neural infrastructure for language. Based on the classical finding of syntactic deficits in patients with Broca's aphasia, it is claimed that Mother Nature equipped the brain with Broca's area in the service of syntax. And since, according to the dominant tradition in linguistics, syntax is the hallmark of natural language, it is Broca's area that should be worshipped as the part of the brain that makes humans unique. This explains why fights over Broca's area seem to stir the emotions stronger than any other brain area. I will try to unpack the, partly implicit, assumptions about Broca's area.

Is there a direct relation between Broca's area and Broca's aphasia? This is doubtful, since the symptoms of Broca's aphasia can occur with lesions in other areas of the brain than Broca's area, and since for lesions involving Broca's area lasting symptoms require the involvement of cortex extending beyond Broca's area. Therefore, deficits in patients with Broca's aphasia are not decisive for our understanding of the role of Broca's area.

Is Broca's area a natural kind in neuroanatomical terms? Certainly not in terms of the cytoarchitectonics of the brain: BA 44 and BA 45 are in this respect clearly different. However, there is a certain similarity in their connectivity profiles.

Is Broca's area a language-specific area? No, it is also known to be involved in other domains of cognition. In other words, Broca's area is multifunctional.

Is Broca's area dedicated to syntax, or even more specific, to syntactic movement? No, since also morphosyntactic operations activate Broca's area. In addition, aspects of semantic unification and phonological processing result in the recruitment of Broca's area.

Do we further our understanding by focusing on an area in isolation if we want to understand the neural infrastructure for complex skills such as language production and comprehension? No, we have to move beyond modern phrenology, and try to understand these functions from an integrated brain network perspective.

Should we trust linguists as our guides towards a neurobiology of language? Well, only to a limited degree. In general, neurobiological accounts of language shouldn't take specific claims or abstract concepts (e.g., traces) of specific linguistic theories too seriously, since there is no agreement (and this is an understatement) among linguists about the proper analysis of natural language. It does not contribute to our understanding of the neurobiology of language if we declare Broca's area a territory for the linguistic wars that are part and parcel of a field that due to the peculiarities of its sociology has seriously impaired its own reputation in, and downgraded its relevance for cognitive neuroscience.

Grodzinsky (continued)

aspects of Working Memory, and perhaps more. This is very much on a par with the visual and the motor systems, in which systematic multifunctionality of brain regions seems to be the rule. I will discuss the multi-functionality of Broca's region in light of some recent developments in visual and motor neuroscience. I will suggest that a characterization of the properties of modular multifunctionality is a key to an understanding of the functional role of Broca's region, and more generally, of the manner the linguistic brain relates to other neurocognitive systems.

Panel Discussion B: Motor Contribution to Speech Perception: Essential or Ancillary?

Friday, October 16 2009, 10:15 a.m. - 12:15 p.m., Avenue Ballroom

Speakers: Luciano Fadiga and Gregory Hickok.

Moderators: Michael Arbib (University of Southern California, US) and Murray Grossman (University of Pennsylvania in Philadelphia, US)

Intro: The discovery of mirror neurons in the macaque brain in the 1990's has revived interest in the notion of perceptual-motor interactions in the nervous system. Mirror neurons are neurons that fire when executing an object-directed action and when passively observing or hearing someone else execute the same or a similar action. Although it remains unclear whether the human brain contains mirror neurons, it has been shown that the human motor system is not only active during the production of speech, but also during the perception of speech. This finding has generated controversy and divergent opinions about the role of the motor system in speech perception. This panel discussion will feature short talks by two researchers at the forefront of this debate, Dr. Luciano Fadiga and Dr. Gregory Hickok. The talks will be followed by a discussion among the panelists and the audience.

The panelists



Luciano Fadiga is Professor of Human Physiology at the University of Ferrara. He obtained his M.D. at the University of Bologna, Italy, and his Ph.D. in Neuroscience at the University of Parma, after which he was a post-doctoral fellow at the University of Bologna. Luciano Fadiga is currently leading a group of researchers at the University of Ferrara, where he continues his research on monkey ventral premotor cortex (to elucidate the physiological mechanisms at the basis of mirror neurons visuomotor response) and on humans (using TMS and fMRI, to reveal the link between action representation and language). Other fields of his research concern attention and its neural mechanisms in normal subjects and patients.



Gregory Hickok is Professor of Cognitive Sciences, Founder and Director of the Center for Cognitive Neuroscience, and co-director of the Auditory and Language Neuroscience Laboratories at the University of California, Irvine. He obtained his Ph.D. in Psychology at Brandeis University in 1991 after which he was post-doctoral fellow at MIT (1991-1993), staff scientist at the Salk Institute (1993-1996), lecturer at UCSD (1994-1996) before joining the faculty at UC Irvine. His research focuses on understanding the functional anatomy of speech and language processing as well as related topics such as spatial hearing, working memory, and sensory-motor integration.

The abstracts

Fadiga

Classical models of language localization in the brain consider an antero-posterior distinction between perceptive and productive functions. In the last 15 years, this dichotomy has been weakened by increasing empirical evidence in favor of a more integrated view. Passive listening to phonemes and syllables activates motor (Fadiga et al., 2002; Watkins et al., 2003; Pulvermüller et al., 2003; Pulvermüller et al., 2006) and premotor areas (Wilson et al., 2004), and more interestingly, motor activations elicited by speech listening are somatotopically organized according to the effector involved in the production of the listened speech sounds (Fadiga et al., 2002; Watkins et al., 2003; Pulvermüller et al., 2006). These results are in line with action-perception-theories stating that motor representations are necessary for perception. However, considering that all the above mentioned studies are inherently correlational, it has been argued that in absence of a stringent determination of a causal role played by motor areas in speech perception, no final conclusion can be drawn in support of motor theories of speech perception (Toni et al., 2008). In fact, the mere activation of motor areas during listening to speech might be caused by a corollary cortico-cortical connection that has nothing to do with the process of comprehension itself. More recently, we designed a series of TMS experiments to tackle the causal contribution of motor areas to speech perception. In one experiment we studied the role of the motor cortex in the discrimination of phonemes produced with the tongue or the lips (lip-related: [b] and [p]; tongue-related: [d] and [t]). To this purpose, on-line TMS pulses were applied either to the lip or tongue motor representations of the precentral cortex just prior to stimuli presentation. Our results show that focal TMS facilitates the perception of those phonemes which are motorically mapped within a given somatotopic district (e.g. [d] and [t] are facilitated by TMS over Tongue M1), and inhibits the perception of the discordant items (e.g. [b] and [p] in this case). In conclusion we demonstrated that activity in the motor system is causally related to the discrimination of speech sounds. More interestingly, this functional association is somatotopically organized according to an effector-sound motor map. Far from being extremists in radically supporting the original formulation of the motor theory of speech perception, our hypothesis is that the motor system provides fundamental information to perceptual processing of speech sounds and that this contribution becomes fundamental to focus attention on others' speech, particularly under adverse listening conditions or when coping with degraded stimuli. References: Fadiga et al., *Eur J Neurosci*, 2002. D'Ausilio et al., *Curr Biol*, 2009. Pulvermüller et al., *Neuroimage*, 2003. Pulvermüller et al., *PNAS*, 2006. Toni et al., *J Physiol – Paris*, 2008. Watkins et al., *Neuropsychologia*, 2003. Wilson et al., *Nat Neurosci*, 2004.

Hickok

Three classes of speech perception models will be considered against empirical data, (1) auditory theories in which word recognition processes are accessed via auditory systems, (2) motor theories in which word recognition processes are accessed via motor systems, and (3) auditory-motor theories in which word recognition processes are accessed via both auditory and motor systems. Empirical evidence unequivocally shows that a pure motor theory is untenable and instead supports an auditory theory with a relatively small top-down influence from the motor system in situations of acoustic ambiguity and perhaps only under restricted task conditions. An alternative to motor theories of speech perception will be presented in which sensory-motor interactions primarily support auditory guidance of speech production rather than motor involvement in speech perception. New lesion data will be presented.

Slide Sessions

Slide Session A

Thursday, October 15 2009, 2:45 - 4:15 p.m., Avenue Ballroom

Chair: Alec Marantz (New York University, USA)

Speakers: Agnes Floel, Giuseppina Rota, Adeen Flinker, Nicole Gage, Dorothee Kuemmerer and Johanna Vartiainen

ABSTRACTS

1. Electrical brain stimulation to enhance verbal learning in healthy individuals and aphasic patients – principle and mechanisms.

A. Floel (1)*, M. de Vries (1), S. Knecht (1), P. Zwiterslood (2), and C. Breitenstein (1). (1) University Hospital of Muenster, Muenster, Germany.* (2) Department of Psychology, Muenster, Germany.

Objectives: Chronic aphasic deficits are the most devastating sequelae of stroke for many patients. We have conducted a series of studies to adapt one promising training-adjuvant strategy, transcranial direct current stimulation (tDCS), to the rehabilitation of language functions. We found faster and better word learning with anodal tDCS over left perisylvian area, as compared to sham (1), and an improvement for grammatical but not chunk-based decisions with anodal tDCS over left prefrontal cortex (2). Methods: We are now examining if anodal tDCS (1mA, 20 min per session) over temporo-parietal cortex, where an increase in activity has been shown to correlate with language training success (3) may improve success of a 10-day intensive language training program (object naming, using the vanishing-cue approach) in chronic aphasic patients. In parallel, we study structural correlates of training + tDCS, using diffusion tensor imaging and voxel-based morphometry (based on magnetic resonance imaging, MRI). Results: In 10 chronic aphasic patients studied so far (anomic aphasia after single left-hemispheric stroke, mean age 62 years), we found that anodal tDCS, combined with intensive training, improved object naming, compared to training combined with cathodal tDCS or with sham ($p < 0.05$). Age and lesion size did not significantly predict the response to therapy. Evaluation of 10 additional patients to substantiate these results, as well as analysis of the structural data (MRI), is on-going. Conclusions: Our results demonstrate that anodal tDCS has the potential to improve language reacquisition in chronic stroke-induced aphasia, similar to what has been shown in the motor domain (4). Analysis of MRI data will answer where the combined tDCS-training approach induces structural changes in task-relevant networks, thereby pointing to potential mechanisms of the intervention. 1. Floel, A., Rosser, N., Michka, O., Knecht, S. & Breitenstein, C. (2008) *J Cogn Neurosci* 20, 1415-22. 2. de Vries, M. H., Barth, A., Zwiterslood, P., Knecht, S. & Floel, A. (2008) *Proceedings of the 14th Conference on Architectures and Mechanisms for Language Processing*. 3. Menke, R., Kugel, H., Deppe, M., Baumgärtner, A., Jansen, A., Schiffbauer, H., Schomacher, M., Knecht, S. & Breitenstein, C. (2006) *Hum Brain Mapp*, conference abstract Florence. 4. Hummel, F., Celnik, P., Giraux, P., Floel, A., Wu, W. H., Gerloff, C. & Cohen, L. G. (2005) *Brain* 128, 490-9.

2. Real-time fMRI and its effect on language learning.

G. Rota (1), G. Dogil (2), N. Birbaumer (3), R. Veit (4), R. and Sitaram (5). (1) Department of Psychiatry, Neurobiology, Pharmacology, and Biotechnologies, University of Pisa Pisa, Italy, Institute for Natural Language Processing, University of Stuttgart, Stuttgart, Germany, Institute for Medical Psychology and Behavioural Neurobiology, University of Tübingen, Tübingen, Germany. (2) Institute for Natural Language Processing, University of Stuttgart, Stuttgart, Germany. (3) Institute for Medical Psychology and Behavioural Neurobiology, University of Tübingen, Tübingen, Germany. (4) Institute for Medical Psychology and Behavioural Neurobiology, University of Tübingen, Tübingen, Germany. (5) Institute for Medical Psychology and Behavioural Neurobiology, University of Tübingen, Tübingen, Germany.

Aim: The present study aimed at clarifying whether subjects can learn to increase activation in the right inferior frontal gyrus, and to test the effect of this volitional control over recognition of emotional prosody. We aimed to uncover changes in functional connectivity of activated brain sites across stages of learning. Moreover, we aimed to shed light on changes in the functioning of the brain at rest as language-task learning progresses and the skill consolidates. Methods: Healthy subjects ($N = 12$, 7 experimental and 5 controls) underwent real time functional magnetic resonance imaging (rtfMRI) training. We used a system based on a 3-T whole body scanner, the Turbo Brain Voyager software and in-house written scripts running on Matlab. We chose the pars triangularis of the right inferior frontal gyrus as target region of interest (ROI target) for regulation. We selected it individually for each subjects using a behavioral task that previously showed to reliably activate this site [1]. We extracted the signal time course in this ROI, transformed it into visual feedback, and used it to guide subjects' learning process in real-time. Before and after training subjects engaged in a prosody identification task and grammaticality judgments. We used a recently developed method [2] to address changes in brain networks' effective connectivity and investigated each training-session of a pilot experimental subject. Finally, we studied changes in activation at rest by modeling rest phases as conditions of interest and comparing each training session for experimental and control subjects. Results: Experimental subjects achieved control over brain activation in the ROI and were able to increase it at will. Their ability to identify emotional prosody

improved as they learnt to contemporarily enhance activation in the ROI. Effective connectivity initially increased in a widespread network of areas involved in speech processing as well as in attentional load and memory recall. In the last phase of training the network shrank to the ROI and “linguistic” regions. Across rest phases we observed a progressively increasing deactivation of the ventro-medial prefrontal part of the default-mode network in those subjects who managed cortical self-regulation. Discussion. We showed that the ability to process speech might improve as an effect of the physiological self-regulation of its cortical underpinnings. This present study provides the first evidence that the modulation of the language system through real-time fMRI affects related performances. We found learning-induced changes in effective connectivity that replicate previous findings [2]. Finally, we uncovered the effect of this learning process on the functioning of the brain at rest supporting existing literature on skill learning [3].

References [1] Dogil G, et al., (2004): Where and how does grammatically geared processing take place and why is Broca’s area often involved? A coordinated fMRI/ERBP study of language processing. *Brain Lang* 89:337–345. [2] Lee S, et al., Cerebral reorganization and efficient brain resource allocation during fMRI-BCI training, to appear in *Hum Brain Mapp* 2009. [3] Argyelan M, et al., (2008): Dopaminergic suppression of brain deactivation responses during sequence learning. *J Neurosci* 28:10687–10695.

3. High density cortical recordings reveal complex suppression and self-speech specificity in the human temporal lobe.

A. Flinker (1), C. Edward (3), H. E. Kirsch (4), N. M. Barbaro (3), N. E. Crone (5), R. T. Knight (2,1). (1) Helen Wills Neuroscience Institute, Univ. of California, Berkeley, Berkeley, CA. (2) Psychology, Univ. of California, Berkeley, Berkeley, CA. (3) Neurosurgery, Univ. of California, San Francisco, San Francisco, CA. (4) Neurology, Epilepsy center, Univ. of California, San Francisco, San Francisco, CA. (5) Neurology, Epilepsy center, Johns Hopkins University School of Medicine, Baltimore, MD.

Corollary discharge signals play a critical role in perceiving our surroundings and are hypothesized to distinguish between internal and external perceptual events. For example, numerous studies across species have shown motor-induced suppression of auditory cortex during vocalization. This effect has been attributed to a corollary discharge (CD) from motor cortex onto auditory cortex. This mechanism is presumed to enhance environmental perception by dampening irrelevant self-generated refferent auditory signals. Human research has previously shown suppression of auditory cortex during vocalization using signal averaging techniques. Using subdural recordings of the human auditory cortex we provide evidence for a CD effect manifested as single-trial suppression of auditory responses during vocalization. Furthermore, using a high density electrode grid we show that a distinct area of middle temporal gyrus (MTG) responds selectively to self-produced speech. We recorded electrocorticographic activity (ECoG) directly from the cortex of patients undergoing neurosurgical treatment. The subjects participated in a phoneme repetition task and were instructed to repeat every sound they heard. All eight subjects showed a robust suppression of high gamma (HG: 70-150 Hz) responses to self-generated sounds in lateral superior temporal gyrus (STG). This suppression was specific to the HG band. One subject was implanted with a high density grid (4mm inter-electrode spacing) covering posterior superior and middle temporal gyri. We observed three distinct types of high gamma responses: responses only during listening, only during self-produced speech and during both. One electrode in MTG showing activity only during speech was surrounded by eight electrodes with activity only during listening. Embedded within this 1 cm² area of cortex, with robust responses to external auditory stimuli, was a site that was selectively activated by self-generated speech. These findings suggest that while many areas of temporal neocortex specialized for auditory processing are suppressed during self-generated speech, presumably the effect of a CD, some areas of auditory cortex are specialized for monitoring auditory feedback. Supported by NINDS Grants NS21135, PO4813, NS061552 and NS40596.

4. Tuning in and tuning out: MEG measures of neural resource allocation for speech and nonspeech in auditory language cortex in typically developing children.

N. M. Gage* (1), A. L. Isenberg (1), P. T. Fillmore (1), K. Osann (2), and M. A. Spence (3). (1) University of California, Irvine, Department of Cognitive Sciences (2) University of California, Irvine, Department of Medicine (3) University of California, Irvine, Department of Pediatrics

A long-debated topic in neurolinguistic research is whether speech is processed in a fundamentally different manner than nonspeech (tonal sounds). In this investigation, we assessed the time course of neural resource allocation for the simplest sounds – sinusoidal tones – and ‘minimal content’ speech sounds – consonant-vowel (CV) syllables. Our aims were to determine i) if neural resources differed for speech vs. nonspeech, ii) if this difference was stable over time (thus with experience), and iii) if it differed in left (LH) and right (RH) hemispheres. We used Magnetoencephalography to measure neural resource allocation in 20 typically developing children (7-14 yrs) to investigate the timecourse of neural responses in auditory language cortex. Children listened to sounds during brief 4-m scans while watching a self-selected movie without sound. There was no task and no overt response was required so that we might measure neural resource allocation in a naturalistic (minimally-attentive) setting. CVs and tones were presented in separate scans and the auditory evoked M100 component was recorded over LH and RH. ‘Neural resources’ were defined as M100 amplitude in root mean square femto Tesla (fT), reflecting population-level neural response. The 1st vs final 100 epochs were compared to determine the timecourse of neural activation. Over a 4-m scan, typically developing children showed ~5% decrease in neural resources in both LH, RH for tones (LH: 1st 127 fT, last 123; RH: 1st 122, last 113) and 15% increase in both LH, RH for speech (LH: 1st 103, last 118; RH: 1st 96, last 110). Next, we assessed the proportional distribution of neural resources in the hemispheres over the course of the scan. For tones, neural resources were equally distributed over LH (.51) and RH (.49) in the 1st block,

but shifted rightward (LH .32; RH .68) by the last block. For speech, neural resources were equally distributed over LH (.52) and RH (.48) and this distribution remained stable (LH .52; RH .48) over the scan. Thus, typically developing children show a dramatic shift in neural resources over the course of just a few minutes, with no task or overt attentional demands, with a gain in neural resources (tuning in?) for more meaningful (speech) sounds combined with a decrease (tuning out?) for less salient tones. The distribution of these resources differed by sound class, with a rightward shift for tones and symmetric distribution for speech. Findings of hemisphere asymmetries that turn on stimulus class for school-aged children may reflect computational biases for tonal and speech sounds that have been shown in healthy adults, with a RH bias for musical sounds and bilaterally-symmetric bias for speech.

5. Voxelwise lesion-behavior mapping of comprehension and repetition deficits in patients with acute aphasia.

D. Kümmerer (1) P. Kellmeyer (1) V. Glauche (1) I. Mader (2) C. Weiller (1) D. Saur (1). (1) Department of Neurology, University Medical Center Freiburg, Germany (2) Department of Neuroradiology, University Medical Center Freiburg, Germany

Introduction Comprehension (COMP) and repetition (REP) are two prototypical tasks which preferentially involve ventral and dorsal processing streams: COMP involves a temporal-prefrontal network which interacts via a ventral pathway along the extreme capsule (EmC), while REP is subserved by a temporal-premotor network which interacts via a dorsal pathway along the arcuate and superior longitudinal fascicle (AF/SLF) (Saur et al., 2008). In this study, we applied voxelwise lesion-behavior mapping (VLBM) to acute left-hemisphere-damaged aphasic patients to evaluate how well the model explains COMP and REP deficits after focal lesions. **Methods** We included 90 patients (mean age 62 y, 61 male) who suffered from an embolic first stroke of the left MCA-territory causing aphasia. Patients were examined 3 (+/-2,6) days post stroke. Behaviourally, they were tested with an aphasia test battery. We focused on the comprehension and repetition subtests and computed individual COMP and REP composite scores. Structural MRI including DWI, FLAIR and a high-resolution T1 anatomical scan was carried out. Lesions were delineated on the DWI or FLAIR scans. Binary maps were normalized to the MNI space using the normalization parameters obtained from the T1 scan. VLBM of the patient group was done using the non-parametric statistics for binary images and continuous behaviour (Brunner-Muntzel) implemented in MRICroN. This resulted in lesion maps for comprehension and repetition. Statistical threshold was set at $p = 0.05$ (FDR corrected). **Results** Comprehension was most frequently affected by lesions within the insula, the superior and middle temporal gyrus, anterior parts of the inferior frontal gyrus, as well as large parts of subcortical tissue. A clear lesion maximum was found within the deep white matter between the basal ganglia and the insular cortex (Fig.1A). Repetition was mostly affected by lesions within the superior temporal gyrus, the parietal operculum and posterior insular cortex, sensory-motor and premotor regions as well as subcortical tissue lateral to the ventricles. Two lesion maxima were found in the deep white matter periventricular (Fig. 1B) and in the posterior insular cortex. **Discussion** These results provide direct lesion evidence for the functional relevance of the proposed dual pathway model for auditory language processing. In particular, comprehension deficits were highly related to white matter damage in projection to the ventral extreme/external capsule fiber system while repetition deficits could be related to white matter damage in projection to the dorsal AF/SLF system. Further analysis, including comparisons of patients with and without comprehension and repetition deficits, are necessary to confirm and further specify these results. **References** Saur D, Kreher BW, Schnell S, Kümmerer D, Kellmeyer P, Vry MS, Umarova R, Musso M, Glauche V, Abel S, Huber W, Rijntjes M, Hennig J, Weiller C (2008). Ventral and dorsal pathways for language. *Proc Natl Acad Sci U S A* 105:18035-18040.

6. Reading isolated words: an MEG-fMRI comparison.

J. Vartiainen (1), M. Liljeström (2), M. Koskinen (3), H. Renvall (4), and R. Salmelin (5). (1)-(5) Brain Research Unit, Low Temperature Laboratory, Helsinki University of Technology, Espoo, Finland.

Magnetoencephalography (MEG) and functional magnetic resonance imaging (fMRI) provide partly differing views of cortical regions involved in reading. MEG has revealed activation in the left occipito-temporal cortex (LOT) that is equal for all letter strings. In fMRI, activation to visually presented letter-strings is detected in the same general region, slightly anterior to the MEG letter-string response, but with the suggestion that the fMRI activation is stronger to real words than to consonant strings (visual word form area, VWFA). Furthermore, the frontal activations are typically more pronounced in fMRI than in MEG. Here we investigated whether fMRI and MEG yield a similar activation pattern in reading when the experimental paradigm, language, and subjects are the same. We measured fMRI and MEG from 15 participants while they were presented with Finnish words, pseudowords, consonant strings, symbol strings, and words embedded in noise. The task was to detect an immediate repetition of the same stimulus. Electroencephalography (EEG) was measured simultaneously with MEG and fMRI to confirm that the subject performed similarly in both recordings. We analyzed evoked responses in MEG and EEG, and blood-oxygenation-level dependent (BOLD) responses in fMRI. The MEG and fMRI data showed activation in the same general regions, in areas typically activated in reading tasks. However, functional differences emerged in the LOT and left inferior frontal gyrus (LIFG). Activation in LOT was detected with both imaging methods. In line with previous studies, MEG activation at ~150 ms was stronger to letter strings than other stimuli. Surprisingly, fMRI showed the strongest response to symbol strings and noisy words throughout the LOT, although the simultaneously measured EEG data indicated equal electrophysiological activation during the fMRI and MEG measurements. In contrast to several previous fMRI studies, our fMRI results did not show differences between words and consonant strings in the LOT. An fMRI control experiment conducted in one individual using a different task that focused on perceptual processing — detection of the string #####

among rapidly presented words, pseudowords, consonant strings and symbol strings — revealed stronger LOTC activation to words and pseudowords than to consonants. The task of the main experiment may thus have induced non-identical demands across the stimulus conditions, resulting in modulation of fMRI activation. The MEG responses in LOTC, however, were similar to those in previous experiments that have employed mainly perceptual tasks. Responses in LIFG were detected using both methods, but only fMRI showed increased responses to words and pseudowords. Possibly, this additional frontal fMRI activation could result from high-level cognitive processing, such as manipulation of semantic information, that is not time-locked to stimulus presentation and, therefore, does not show in the MEG evoked responses. In conclusion, our results indicate that MEG and fMRI activations are not equally affected by task demands. MEG activation in LOTC seems to emphasize bottom-up processing of written words as it is not modulated by the task. In contrast, fMRI effects are dependent on the task and may also reflect top-down modulation.

Slide Session B

Friday, October 16 2009, 2:45 - 4:15 p.m., Avenue Ballroom

Chair: Richard Wise (Imperial College, London, UK)

Speakers: Branch Coslett, Benjamin Stengel, Ingo G. Meister, Raphael Fargier, Laura Menenti, and Ina Bomkessel-Schlesewsky

ABSTRACTS

I. VLSM shows anterior temporal involvement in semantic word retrieval.

H. B. Coslett (1,2), D. Y. Kimberg (1), G. Walker (1), O. Faseyitan (1), A. Brecher (2), G. S. Dell (3), and M. F. Schwartz (2). (1) University of Pennsylvania, Philadelphia, USA (2) Moss Rehab Research Institute, Philadelphia, USA (3) University of Illinois, Urbana-Champaign, USA

Introduction The task of naming pictures invokes semantically-driven lexical retrieval, as shown by the occurrence of semantic errors in healthy speakers and, more prominently, people with aphasia. To examine the brain basis of semantic word retrieval, this study mapped the lesions associated with semantic naming errors in post-stroke aphasia using voxel-based methods. **Methods** We report on 64 right-handed English speakers (42% female; 48% minorities) with left hemisphere stroke and aphasia. Mean for age was 58 ± 11 , education, 14 ± 3 ; months post onset, 68 ± 78 , and WAB AQ (76.8 ± 15.2). From the 175-item Philadelphia Naming Test (PNT), the semantic error score (SemErr) was computed as a proportion of total items. Additionally, standard scores on four semantic comprehension tests were averaged to create a measure of core semantic processing (CoreSem). Lesions from patients with recent high-resolution MRI scans [$n = 34$] or CTs [$n = 30$] were segmented manually and registered to a standard $1 \times 1 \times 1$ mm template. In each voxel that was lesioned in at least 5 patients, a t-test was computed comparing SemErr scores between patients with and without lesions in the voxel. The resulting t-map was thresholded to control the False Discovery Rate (FDR) at 0.01. In a second analysis, errors arising during conceptualization were factored out by mapping the (SemErr – CoreSem) residuals. **Results** We found 25,669 voxels for which there was a significant correlation between lesion status and SemErr. The highest t-value voxels were in left anterior temporal lobe (ATL); the highest concentration was in the middle temporal gyrus and the temporal pole. Clusters of significant voxels were also found in the posterior portion of the middle temporal gyrus (lateral and superior portion of BA 37), and in the inferior and middle frontal gyri (BA 45 and 46). There were no significant voxels in the posterior superior temporal gyrus (Wernicke's area); peak t-values here were approximately 1.8, far below the critical t (3.86). Filtering out CoreSem changed the strength of effects but not the pattern (see Figure 1). The majority of significant voxels (7,332) were in the mid- and anterior temporal lobe, thus implicating this region, specifically, in the mapping from semantics to lexical items during production. **Discussion.** Aphasia lesion studies have long linked semantic word retrieval to left posterior temporal and parietal regions. Instead, we found the strongest effects in mid- and anterior temporal lobe. Drawing on evidence from semantic dementia (Patterson, Nestor & Rogers, 2007) and functional neuroimaging (Indefrey & Levelt, 2004), we suggest that this role is one of transmitting information from an ATL semantic hub to lexical representations localized in the mid part of the left middle temporal gyrus. **Acknowledgements.** Support provided by NIH grant #RO1DC000191. **References** Indefrey, P., & Levelt, W. J. M. (2004). The spatial and temporal signatures of word production components. *Cognition*, 92(1-2), 101-144. Patterson, K., Nestor, P. J., & Rogers, T. T. (2007). Where do you know what you know? The representation of semantic knowledge in the human brain. *Nature Reviews Neuroscience*, 8, 976-987.

2. Distinct modality-specific knowledge systems identified with functional connectivity fMRI.

B. C. Stengel (1), J. R. Binder (1), C. Humphries (1), R. H. Desai (1), and M. S. Seidenberg (2). (1) Medical College of Wisconsin, Milwaukee, US (2) University of Wisconsin-Madison, Madison, US

According to sensory-motor accounts of semantic memory, concept knowledge is partly represented in modality-specific perceptual systems through which the concepts are acquired. We hypothesize that these modality-specific systems form distinct networks with correlated spontaneous signal fluctuations. Results from a task-related functional magnetic resonance imaging (fMRI) study investigating the modality-specific semantic network, combined with resting-state fMRI (rs-fMRI), was used to uncover underlying modality-specific network connections in addition to connections with "supramodal convergence zones" of the semantic network. In this study, participants learned associations between sets of bird names and modality-specific information for each set: bird pictures (Visual condition), bird calls (Auditory), and verbal statements (Facts). During task-related fMRI, participants performed a similarity-rating task in which two bird names from the same training condition were visually presented and participants rated how similar the two birds were on a scale from 1 to 4. Resting-state fMRI data were collected during a second scanning session. For task-related fMRI, bilateral parahippocampal, fusiform and inferior temporal gyri showed greater activity for Visual over other conditions. The left posterior superior temporal, supramarginal and inferior frontal gyri showed greater activity for Auditory over other conditions. The left angular and bilateral posterior cingulate gyri showed greater activation for Facts over other conditions. These areas were used as seeds for correlation analyses of the rs-fMRI data. Seed locations from each condition were associated with a network of correlated areas within the rs-fMRI data that was similar to the corresponding task activation map for the same condition. In addition to these modality-specific regions within each network, common temporal lobe regions previously associated with semantic processing were found in each of the networks, suggesting shared connectivity with supramodal convergence zones of the semantic network. These results support the hypothesis that modality-specific perceptual systems used for acquiring conceptual knowledge are spontaneously active and form distinct networks even in the absence of externally imposed task conditions.

3. Temporal- and Muscle-Specific Activation in the Primary Motor Hand Area during Conceptual and Phonological Tasks.

I.G. Meister (1), A.D. Wu (2), C. Deblieck (2), M. Iacoboni (2). (1) University Hospital Cologne, Cologne, Germany (2) University of California at Los Angeles, Los Angeles, USA

Theoretical considerations and empirical findings have suggested a role of motor structures in language. For instance, lexical access is facilitated by hand gestures in healthy subjects and neurological patients. However, the specificity of motor activation during linguistic processing is not clear. In the present study Transcranial Magnetic Stimulation was applied to the hand area of the primary motor cortex while subjects performed tasks requiring perceptual or linguistic processing of object-oriented hand actions. Motor Evoked Potentials were recorded in two hand muscles, one of them more involved in execution of the observed actions than the other. Results showed an increase of the excitability of the hand area of the primary motor cortex during action observation and conceptual or phonological tasks related to the observed object-directed actions. The increased motor excitability was muscle-specific (i.e., restricted to the hand muscle involved in the observed action), specific for the left hemisphere, and specific for one time point (400ms after stimulus onset). This time window is associated with converging conceptual, semantic and phonological processes. Muscle-specific motor excitability was higher during the tasks involving phonological processing and lexical access. The specificity of the involvement of cortical motor structures during linguistic tasks suggests a coupling between the manual motor system and language, which may mediate the facilitation of lexical access through hand gestures in healthy subjects and in neurological patients with language disorders.

4. Monitoring the emergence of shared neural networks between perception, action and language structures: An analysis of oscillatory brain dynamics.

R. Fargier (1), Y. Paulignan (1), V. Boulenger (2), P. Monaghan (3) and T. Nazir (1). (1) Laboratoire sur le langage, le cerveau et la cognition, Bron, France (2) Dynamique Du Langage, Lyon, France (3) Lancaster University, United Kingdom

Recent studies on cerebral language processes point to the involvement of sensory and motor cortex in the understanding of words. However, despite evidence for shared neural networks between perception, action and language structures, little is known about how they emerge. Based on the hypothesis that such shared circuits could result from Hebbian learning the present study addressed this question by monitoring the impact of acquiring arbitrary associations between novel verbal stimuli and motor actions on electroencephalographic mu rhythm suppression. The mu rhythm (8-12 Hz) is generated by sensorimotor cortex and is present at rest but suppressed during execution of motor movements. Mu rhythm is also suppressed while observing a movement or while listening to action-related sounds. Here we show that listening to verbal stimuli learned in the context of the execution of a movement can trigger that suppression. For this, participants were trained on two consecutive days to associate pseudo-words or backward speech to video clips of object-oriented hand and arm movements or animated images. Time-frequency analysis that focalized mu rhythm reactivity during perception of the isolated verbal stimuli (probed at four different periods during training) showed that while mu rhythm reactivity before training was the same for verbal stimuli associated with motor actions or with images, differences between the two types of verbal stimuli emerged with training. Perception of verbal stimuli that were experimentally associated with a movement lead to mu suppression while perception of verbal stimuli associated with images increased mu rhythm reactivity. These results show that shared circuits between language and action can emerge very rapidly. If such shared circuits help consolidating word meaning

such training may be useful for rehabilitation of language deficits.

5. Semantics, words, syntax: repetition suppression in sentence comprehension and production.

L. Menenti (1), S. Bihler (1,2), K. Segaert (1,2), and P. Hagoort (1,2). (1) Radboud University Nijmegen, Donders Institute for Brain, Cognition and Behaviour, Nijmegen, the Netherlands (2) Max Planck Institute for Psycholinguistics, Nijmegen, the Netherlands

Introduction: When speaking, we compute a message, formulate a syntactic structure and articulate the sentence. For comprehension of sentences, complementary processes occur. In this fMRI study we investigate to what extent comprehension and production rely on the same processes by using an fMRI adaptation paradigm to investigate brain areas sensitive to semantic, lexical and syntactic processes in both speaking and listening. fMRI adaptation is a phenomenon whereby repeating specific properties of stimuli reduces the BOLD response in areas sensitive to these properties. By independently manipulating semantic, lexical and syntactic repetition across subsequently pronounced or heard sentences we distinguished sets of areas sensitive to these properties. Methods: Forty-four participants took part in either a picture description (production) or picture-sentence matching (comprehension) paradigm in fMRI. In both experiments, participants watched pictures with two actors depicting transitive events such as hit, kiss, greet. In production, participants described them. Color-coding forced them to use either a passive or an active sentence. In comprehension, participants listened to the sentences. Subsequently produced or heard sentences were independently repeated in semantic, lexical and syntactic content. See figure 1 for design and stimulus examples. Results: The bilateral posterior middle temporal gyrus (BA37) showed repetition suppression for semantic priming in both comprehension and production. The conjunction of lexical priming effects in comprehension and production revealed clusters in left inferior frontal gyrus (LIFG; BA45/47) and posterior LMTG (BA37). Two areas were sensitive to syntactic priming both in comprehension and production: LIFG (BA44/6) and posterior LMTG (BA21/22). All effects reported based on conjunction analyses across experiments, $p < .05$ cluster-level corrected for multiple comparisons. Conclusion: Comprehension and production of sentences rely on grossly overlapping neural systems. Lexical and syntactic processing are associated with classic left-hemispheric language areas (LIFG, LMTG), but sentence-level semantic processing involves both hemispheres (MTG). This is the first study investigating lexical, semantic and syntactic processes simultaneously, and the first to directly compare the neural systems underlying sentence production and comprehension for these processes.

6. Cross-linguistic variation in semantic P600 effects: evidence for a new perspective on the syntax-semantics interface and a neurophysiological basis for language classification.

I. Bornkessel-Schlesewsky (1,2) M. Schlewsky (3). (1) University of Marburg, Marburg, Germany (2) Max Planck Institute for Human Cognitive and Brain Sciences, Leipzig, Germany (3) Johannes Gutenberg-University, Mainz, Germany

The long-standing assumption of a direct correspondence between event-related potential (ERP) components and linguistic subdomains (i.e. N400 = lexical-semantics; P600 = syntax) has become increasingly controversial in recent years, with N400 effects observed in response to manipulations that would typically be considered syntactic (e.g. Haupt et al., 2008; Choudhary et al., in press) and P600 effects elicited by semantic manipulations (e.g. Kolk et al., 2003; Kuperberg et al., 2003). These observations either call into question the informativity of ERP components for linguistic distinctions or suggest that the functional subdivisions typically assumed are empirically inadequate. A proposal with respect to how the divisions between syntax and semantics might be redrawn has been put forward within the scope of a cross-linguistically oriented neurocognitive model of language comprehension, the extended Argument Dependency Model (eADM; Bornkessel & Schlewsky, 2006). In this model, sentence-level interpretation is accomplished via linking principles which encompass both syntactic (e.g. case marking) and semantic (e.g. animacy) information. Linking, which operates upon a word category-based input, applies in parallel to lexical/associative processing, with the two information sources combined in a subsequent “generalised mapping” step. It was recently demonstrated (Bornkessel-Schlesewsky & Schlewsky, 2008) that this independently motivated architecture can account for semantic P600 effects in reversal anomalies in English and Dutch (e.g. in *The hearty meals were devouring ...*, from Kim & Osterhout, 2005). As linking is solely a function of argument position in English/Dutch, an animacy mismatch does not lead to a linking conflict. For languages in which linking draws upon a range of information types (e.g. case, animacy), reversal anomalies are predicted to elicit linking-based N400 effects. Here, we show that this prediction is indeed borne out. We will present three ERP experiments on animacy-induced semantic reversal anomalies in German, Turkish and Chinese. In all three languages, the processing conflict engendered an N400. In contrast to English, all of these languages have a free word order and require the use of multiple information types in linking (including animacy). The data from German additionally show that the N400 is followed by a late positivity when the conflict cannot be resolved (e.g. via word order reanalysis). A fourth experiment examined Icelandic, a language with a strict word order but a rich case marking system. Crucially, Icelandic allows for the construction-specific manipulation of linking-relevant features depending on verb type: with certain verbs, argument position is the primary determinant of linking (akin to English); with others, case marking is most important (akin to German/Turkish). Strikingly, ERPs showed a P600 for reversal anomalies in the former and an N400 in the latter case. From this overall pattern of results we conclude that semantic P600s are a language-specific phenomenon, occurring only in languages of the English/Dutch type. Furthermore, semantic P600s are only problematic for models of language comprehension if these are based on a classical subdivision between syntax and semantics. Within the scope of the eADM, the N400-P600 distinction is informative for a “neurotypological” classification of languages with respect to their linking characteristics.

Poster Sessions

Poster Session A

Thursday, October 15 2009, 4:15 – 6:45 p.m., Halsted Room.

ABSTRACTS

Comprehension

1. Killing a novel metaphor and reviving a dead one: ERP correlates of metaphor conventionalization. *M. Faust (1), Y. Arzouan (1), and A. Goldstein (1). (1) Bar-Ilan University, Ramat Gan, Israel.*

Everyday language is highly dynamic and the perceived meaning is adapted to context that is constantly and rapidly changing. One aspect of this flexibility is how words are combined in novel ways to form original figurative meanings. While novel metaphors are created de novo, some of them become conventional and even "dead" with repeated use, losing their original literal meaning. The career of metaphor model (Bowdle & Gentner, 2005) postulates a shift in mode of mapping from comparison to categorization as metaphors are conventionalized. Although there is behavioral evidence to support this model, the neural correlates of this processing shift have yet to be studied. In the present study we investigated whether the processing of novel metaphors, as revealed in ERP waveforms, would change after inducing a metaphoric category merely by having participants explain the meaning of an expression. During the initial exposure phase, participants performed a semantic judgment task with two-word expressions consisting of literally related pairs, conventional and novel metaphoric expressions and unrelated words. For half of the word pairs participants rapidly judged whether the word pair formed a meaningful expression or not. For the other half, in addition to the semantic judgment task, participants were asked to shortly explain the meaning of the expression. In the test phase, participants performed the semantic judgment task again while their brain activity was recorded by EEG. We found that the waveforms elicited by novel metaphors became similar to those elicited by conventional ones when participants had explained their meaning during the previous exposure. Explaining novel metaphoric expressions reduced the amplitude of the N400 and increased the amplitude of the late positive component. Interestingly, after participants explained the meanings of conventional metaphors, these metaphors elicited waveforms that resembled those of novel metaphors, reflected by greater N400 and smaller late positive complex amplitudes. In contrast, the waveforms of literal expressions were similar in the explained and unexplained conditions. Our results suggest that given the right circumstances, people are able to conventionalize novel metaphors and change their processing mode quickly, and this change may be the one aspect of the magic of poetry. Furthermore, the findings indicate that conventional (dead) metaphors, even though they might seem to act like literal relations or categories and appear to have lost their alternative meaning, may still retain properties that can be revived and picked up by brain activity measures. These findings may lead the way for understanding the mechanisms that promote creative thinking. Thus, the change in the processing of conventional metaphors seems to suggest that in the context of unmapped concepts, the structural mappings of fixed relations might be restructured by providing the adequate conditions for inducing reanalysis. People can be driven to restructure old material in a novel way by encouraging rethinking while attempting to link previously unrelated notions.

2. Contextual effects on conceptual blending in metaphors: an event-related potential study. *F. Yang (1), M. Huq (1), K. Lipowski (1), M. Brier (1), and D.C. Krawczyk (1,2). (1)University of Texas at Dallas, Texas, US (2) UT Southwestern Medical Center, US*

Blending theory proposes that metaphor involves mappings between elements in two distinct domains and integration of information from these two domains. Previous event-related potential (ERP) studies suggested that literal mapping occurred during metaphor comprehension. However, it was unclear whether access of the literal meaning facilitates or inhibits metaphor comprehension and little is known regarding the contextual factors affecting blending. The present study uses a stimulus 1 (probe)-stimulus 2 (sentence) paradigm to study the effect of literal mapping on metaphor comprehension using probe words from different domains and to investigate the effect of semantic congruence on blending using irrelevant and relevant probes. ERPs were recorded when 18 participants were reading short novel metaphors (e.g., The girl is a lemon) or literal control sentences (e.g., The fruit is a lemon) preceded by either a relevant or irrelevant word. The relevant words preceding metaphors represented either a concept in the target (metaphoric) domain (e.g., sarcastic-The girl is a lemon) or a concept of the source (literal) domain (e.g., sour-The girl is a lemon). The results revealed that N400 amplitudes of the source (literal) probe-metaphor pairs were bigger than that of the target (metaphoric) probe-metaphor pairs. This suggests that literal mapping context actually inhibited blending maybe due to competition of semantic features of source and target meanings. However, the analysis of the late positive components (P600) revealed that significantly larger amplitudes of the target probe-metaphor pairs than the source probe-metaphor pairs, suggesting that metaphoric domains were more difficult to reanalyze than literal domains. Moreover, significant difference in P600 amplitudes between irrelevant and relevant pairs was observed. This indicated that sentences with incongruent context were more taxing for reanalysis in both metaphors and literal

sentences. We conclude that presence of literal meaning inhibits conceptual integration and that the demands of conceptual reanalysis affect the difficulty of in both literal and metaphorical languages.

3. Category-specific deficits and sensory-motor knowledge: connectionist models. R. H. Desai (1), S. Chambers (2), J. R. Binder (3), D. Medler (4), A. Arnoldussen (5), L. L. Conant (6), M. S. Seidenberg (7). (1)(2)(3)(4)(6) Medical College of Wisconsin, Milwaukee, US. (5)(7) University of Wisconsin, Madison, US.

A prominent theory of organization of semantic knowledge in the brain suggests that concepts are organized according to categories that are evolutionarily important, such as living things, artifacts, or animals. An alternative theory suggests that the sensory-motor modality through which knowledge is learned and used plays an important part in this organization. Different natural categories rely on various sensory-motor dimensions to different extents, and hence the organization may appear to be category-specific. We collected sensory-motor attribute ratings for a large set of words in the domains of Motion, Sound, Manipulation, Color, Shape, and Parts. A simple feed-forward connectionist network with one hidden layer was trained to classify words into Plants, Animals, or Artifacts, given these six ratings. The network was trained on 50% of the 306 nouns that fall into one of these categories in the dataset, and tested on the other half. It archived an overall classification rate of 94.5% (± 1.4), thus showing that object concepts can be categorized purely on the basis of sensory-motor attributes. Next, we introduced damage to the network weights, such that the transmission of various input attributes to the hidden layer is disrupted. The network showed category-specific deficits with damage to different attributes. Damage to the Manipulation information resulted in a Nonliving > Living deficit. With damage to Color information, a Living > Nonliving deficit was observed. Damage to the Motion information caused a selective deficit for Animals. All of these deficits have been reported in patients and cited as evidence for category-specificity. This demonstrates that the underlying cause of what appear to be category-specific deficits may not be damage to categorical representations per se, but selective disruption of sensory-motor knowledge. Using the attribute ratings we also trained a self-organizing map that performs unsupervised clustering of the input patterns in a biologically plausible manner. The resulting map was examined using input patterns from different categories. Without any specifications of relevant categories during training, partially distinct clusters were formed for the categories of Animals, Artifacts and Plants, based on the importance of different sensory-motor properties (e.g., Color is more important for Plants and Animals, Motion for Animals, and Manipulation for Artifacts). This simulation mechanistically demonstrates how sensory-motor inputs can result in formation of clusters of neurons in the brain that differentially represent categories, without any explicit specification of categories during the process.

4. Conceptual mappings as comparison in metaphor comprehension. V. T. Lai (1) and T. Curran (2). (1) University of Colorado, Boulder, US (2) University of Colorado, Boulder, US.

Metaphors are central for communication, but the neural mechanisms underlying metaphor comprehension are not fully understood. Most behavioral studies found that metaphorical expressions were read as fast as literal ones, suggesting that metaphorical meanings were readily available as the literal ones. However, several ERP studies (Coulson & Van Petten 2002) found that people experienced more difficulty integrating words in metaphorical than in literal contexts, suggesting some processing effort for semantic integration. We propose that such processing effort is due to retrieving/creating conceptual mappings from one concept to another (Lakoff 1993), consistent with models that propose an initial stage of structure mappings (Gentner & Wolff 1997). We also propose that the cognitive process underlying both conventional and novel metaphors is comparison, as opposed to categorization (i.e., assertion of category membership) (Bowdle & Gentner 2005). Experiment 1 tested the idea of conceptual mappings and hypothesized that repeated exposure to relevant mappings first could facilitate metaphor comprehension. We used prime-target pairs of metaphorical sentences from the same metaphor (e.g. prime "I can see the path of his life", target "Life can sometimes be bumpy", both from the conventional metaphor "LIFE IS A ROAD"; prime "I can see the path of his idea", target "Ideas can sometimes be bumpy", both from the novel metaphor "IDEAS ARE LIKE ROADS"). Conventionality was confirmed by pretests of familiarity and interpretability, and cloze probabilities were matched. Literal and anomalous sentences matched syntactically- and lexically- across conditions were used to control for structural and lexical priming effects. In the unprimed conditions, literal sentences were used as neutral primes preceding the target metaphorical sentences (e.g. "She borrowed some books from the library"). Sentences were presented word-by-word in a sensicality judgment task. ERPs to the sentence-final words were analyzed. The results showed that the unprimed conditions replicated previous research and found a significantly more negative N400s for metaphors vs. literal sentences. Crucially, significant N400 priming effects were found for conventional metaphors and some effect for novel metaphors, suggesting that conceptual mappings were in use. Experiment 2 hypothesized that comparison thinking was responsible for retrieving/creating conceptual mappings in both conventional and novel metaphor comprehension. We elicited comparison thinking by using similes as primes (e.g. simile-prime "LIFE IS LIKE A ROAD" for conventional metaphors, simile-prime "IDEAS ARE LIKE ROADS" for novel metaphors). The same metaphorical sentences used as targets in Experiment 1 were used as target sentences here. In the unprimed conditions, literal statements were used as neutral primes (e.g. "A typhoon is like a hurricane"). Results for the unprimed conditions replicated those in Experiment 1. Importantly, significant N400 priming effects were obtained for both conventional and novel metaphorical sentences, suggesting that the comparison process elicited by similes helped metaphor comprehension. Our findings offered evidence for a qualitative difference in the way literal and metaphorical language is processed. Metaphorical sentences were more cognitively taxing than literal sentences, possibly due to an initial stage of conceptual mappings. In addition, comparison plays an important role for both conventional

and novel metaphor processing.

5. Meaning constitution of proper names and figurative expressions. *H.M. Müller, and S. Weiss. Center of Excellence "Cognitive Interaction Technology", University of Bielefeld, Germany.*

It is still an open question how lexical and conceptual knowledge is represented in the human brain. Knowledge on the inner structure of the mental lexicon is necessary for theories e.g., on language learning, language therapy of aphasics or computer based communicators in artificial intelligence (cognitive interaction technology). In this study, we investigated processing differences between proper names vs. nouns and the constitution of figurative meaning of ambiguous and unambiguous sentences. We investigated the reception of German spoken language using the analysis of EEG coherence [4]. Based on theoretical considerations the discussion about a special status of nomina propria within the class of nouns has a long tradition. Since prototypical proper names are monoreferential (e.g., Susan or Cape of the Good Hope) and not providing a conceptual meaning, processing differences in comparison to common nouns (e.g., flower, chair) are shown. In addition, neuropsychological findings of brain damaged patients with selective deficits e.g., a better comprehension of either proper names or common nouns, support this. In comparison to common nouns, processing of first names shows a faster neuronal response and a frequency specific activation in right hemispheric areas in addition. Another occurrence of a fixed sense of a phrase is the meaning constitution of figurative expressions ("He drives his father around the bend" vs. He drives his father around the country"). Linguistic theories assume different models for processing figurative compared to literal language: e.g. the standard pragmatic model assumes literal priority in understanding figurative language whereas other models suggest e.g. a parallel processing of both meanings, a direct access to the figurative meaning without literal analysis or access dependent on a keyword in a figurative sentence [1]. Specific brain damage reduces the ability of understanding figurative language [2]. Furthermore, it is shown with brain mapping techniques that processing of figurative language involves parts of the right hemisphere in addition to the language areas in the left hemisphere [3]. Our results support the assumption of similarities in neuronal processing of proper names and the figurative meaning of sentences. Both conditions elicit synchronization within the left and the right hemisphere. In addition, the results for figurative sentences show that neuronal processes only differ from the moment on the figurative meaning is retrieved and neither the left nor the right hemisphere alone but cooperation between the hemispheres plays the most important role. [1] Glucksberg, S. (2001) (ed.). Understanding figurative language. From Metaphors to Idioms. Oxford: University Press. [2] Papagno, C. & Tabossi, P. (2002). *Brain Lang*, 83: 78-81. [3] Bottini, G. et al. (1994). *Brain*, 117: 1241-1253. [4] Weiss, S. & Mueller, H.M. (2003). *Brain Lang*, 85: 325-343.

6. Hemispheric asymmetry for meaning: Evidence from lexical ambiguity resolution in Hebrew. *O. Peleg (1) Z. Eviatar (1). (1) University of Haifa, Haifa, Israel.*

Research using the divided visual field (DVF) paradigm has led to the conclusion that the two hemispheres differ significantly in the way they deal with homographs like bank: In the left hemisphere (LH), all meanings are immediately activated and shortly afterwards, one meaning is selected on the basis of frequency and/or contextual information. In contrast, the right hemisphere (RH) activates both meanings more slowly and maintains these meanings irrespective of context or frequency. On the basis of such findings, current hemispheric models have converged on the proposal that LH language processing is relatively more focused, faster and takes place at higher levels of analysis. We propose an alternative explanation for these reported asymmetries. According to our proposal, in the LH, orthographic, phonological, and semantic representations are fully interconnected. In contrast, in the RH, orthographic and phonological representations are not directly connected. When orthographic and phonological representations are unambiguously related, related meanings are immediately boosted by both visual and phonological sources of information. As a result, meaning activation is faster in the LH. However, when a single orthographic representation is associated with multiple phonological representations, meanings may be more difficult to activate in the LH due to the competition between the different phonological alternatives. To test our proposal, we investigated the disambiguation of homophonic versus heterophonic homographs in the two hemispheres. Both types of homographs have one orthographic representation associated with multiple meanings. They are different however in terms of the relationship between orthography and phonology. Thus, in contrast to the received view, we predicted that RVF/LH advantage in multiple meaning activation may be lost (or even reversed) in the case of heterophonic homographs. In a series of DVF priming experiments and computational simulations, we demonstrate that this conclusion is too strong and that the LH advantage in lexical selection is qualified by the phonological status of the homograph. Specifically, LH advantage can be eliminated and even reversed in the case of heterophonic homographs such as wind. We show that there are different timelines for ambiguity resolution for homophones and heterophones in the cerebral hemispheres, under different sentential context conditions.

7. The anatomy of semantic memory. *G. de Zubicaray (1), S. Rose (1,2), and K. McMahon (1). (1) Centre for Magnetic Resonance, University of Queensland, Brisbane, Australia. (2) Centre for Clinical Research, University of Queensland, Brisbane, Australia.*

Introduction: Much of what we know about the anatomical structure and connectivity of semantic memory is derived from patient studies. For example, patients with semantic dementia (SD) experience a progressive deterioration in semantic or conceptual knowledge that is associated with a loss of grey matter (GM) volume occurring predominantly in the anterior temporal lobes on structural magnetic resonance imaging (MRI; Rogers et al., 2006). Studies in patients with cerebrovascular

lesions have also implicated a portion of the left posterior middle and superior temporal gyri (Cloutman et al., 2008). Finally, electrical stimulation studies conducted prior to patients undergoing surgery for tumour resection indicate that the left inferior fronto-occipital fasciculus (iFOF) may be a prominent white matter (WM) pathway in the connectivity of the semantic system (Duffau et al., 2005). To date, no studies have examined the structure and connectivity of the normal semantic system. We addressed this issue using structural MRI and high angular resolution diffusion imaging (HARDI) in a group of healthy older adults. Methods: Participants were 55 healthy older adults (29 male) aged between 55 and 85 years. Structural T1-weighted 3D MRI scans (256 slice, 0.9 mm isotropic resolution) were acquired using a 2 Tesla Bruker Medspec system. HARDI data comprising 60 images (45 × 2.5 mm slices, 0.9 × 0.9 mm resolution, 16 B0, 44 gradient directions) acquired on a 1.5T Siemens Sonata system were available for a subset of participants (N = 29). Participants' scores on 6 'semantic' tests (Pyramids and Palm Trees, Boston Naming, PALPA Sentence-Picture Matching, Semantic Fluency, and Information and Similarities subtests of the WAIS-III) were entered into a principal components analysis (PCA), and a single component comprising 40% of the variance was extracted. Component scores were regressed against GM volume estimates derived from the T1 images using voxel based morphometry (VBM) in SPM5, and against the HARDI data with tract based spatial statistics (TBSS) in FSL. Age and a measure of overt speech production (phonological fluency) were included as nuisance covariates. Results: The VBM analysis revealed that semantic memory (as indexed by the participant's PCA scores) showed significant relationships with GM volume in several left hemisphere regions: temporal pole, posterior middle and superior temporal gyri, inferior parietal lobule (IPL), and striatum. A significant relationship was also observed with right fusiform gyrus GM volume. The TBSS analysis revealed a significant relationship with the left iFOF WM fibre tract. Discussion: The VBM results in the anterior and posterior temporal regions are consistent with those reported by patient studies (Cloutman et al., 2005; Rogers et al., 2006), while the TBSS result of a significant relationship with the left iFOF pathway corroborates findings from electrical stimulation studies (Duffau et al., 2005). Of interest, the additional regions found in the VBM analysis (left striatum and IPL, right fusiform) are often reported in functional imaging studies of semantic processing. References: Duffau, H., et al. (2005). *Brain*, 128, 797–810. Cloutman, L. et al. (2008). *Cortex*, 45, 641–649. Rogers, T., et al. (2006). *Cognitive, Affective, & Behavioral Neuroscience*, 6, 201–213.

8. The impact of attention on semantic processing in the brain: Evidence from lexical ambiguity in speech comprehension. J. E. Peelle (1), R. J. Eason (1), J. M. Rodd (2), M. H. Davis (1). (1) MRC Cognition and Brain Sciences Unit, Cambridge, UK (2) University College London, London, UK.

Successful speech comprehension requires assigning an appropriate conceptual meaning to words extracted from a complex acoustic signal. Words that have multiple meanings pose a special challenge, as the appropriate meaning for these items must be inferred from their surrounding context. For example, the word "bark" could refer to the noise made by a dog or the outer covering of a tree, but its meaning is clear in the sentence "Jack was startled by the loud bark". Disambiguating sentences containing these words has been shown to recruit additional processing in regions of the brain supporting semantic processing, including left inferior frontal gyrus (IFG), left posterior middle temporal gyrus (MTG) and left posterior inferior temporal cortex [Rodd et al. (2005) *Cerebral Cortex* 15:1261-1269]. Although speech processing is often presumed to be largely automatic, the degree to which these disambiguation processes can operate outside directed attention is unknown. In the current study we addressed this issue using functional magnetic resonance imaging (fMRI) to monitor brain activity during presentation of concurrent auditory and visual tasks. Eighteen healthy participants (aged 18-30) with normal hearing were presented with spoken sentences containing at least two ambiguous words (high-ambiguity stimuli), psycholinguistically matched sentences without ambiguous words (low-ambiguity stimuli) and signal-correlated noise (SCN). Two tasks were always simultaneously presented: an auditory task involving listening to the sentences or SCN, and a visual task involving detecting targets among alternating simple patterns. Attention was directed to a particular task using explicit instructions prior to each scanning run, producing Attend Auditory and Attend Visual conditions. In addition to the fMRI data we collected two post-test behavioral measures of sentence processing: recognition memory scores (expressed as *d'*) and free association responses for presented ambiguous words. For the latter we calculated the proportion of generated words related to the meaning heard during scanning, under the assumption that deeper semantic processing during initial presentation would exert a greater influence on subsequent word generation. Behaviorally, participants showed more accurate recognition memory for the Attend Auditory sentences than the Attend Visual sentences, supporting the efficacy of our attentional manipulation. The post-test word association task showed that listeners generated significantly more meanings related to the presented words in the Attend Auditory condition, consistent with increased semantic processing. Importantly, however, performance on all measures was significantly above chance in the Attend Visual condition, indicating listeners were still able to process sentences even when attention was reduced. Finally, we turned to the fMRI data for converging evidence regarding the role of attention in ambiguity processing. As shown in Figure 1a, brain regions that showed increased activity for high-ambiguity > low-ambiguity sentences, collapsing across attention condition, were consistent with previous studies and included left IFG, left fusiform gyrus, and left posterior MTG. Of primary interest was the Ambiguity × Attention interaction, shown in Figure 1b, which was significant in dorsal regions of left IFG (Brodmann areas 44/45), but not elsewhere. Together, our findings support a critical role for directed attention in the processing of ambiguous speech.

9. The neural correlates of basic linguistic composition: an MEG investigation. D. K. Bemis (1), L. Pykkänen (2). (1) New York University, New York, US. (2) New York University, New York, US.

Introduction To date, investigations into the neural correlates of linguistic combinatorial operations have focused primarily upon the processing of complete sentences. For basic syntactic composition, the left anterior temporal lobe (LATL) has been implicated by several studies that show activity in this region increases during the comprehension of sentences compared to word lists (e.g. Humphries et al., JCN, 2006) and correlates with measures of syntactic complexity during naturalistic story listening (Brennan et al., submitted). When syntactic complexity is held constant, constructions demanding greater semantic composition elicit increased activity in the ventromedial prefrontal cortex (VMPC) (e.g. Pylkkänen & McElree, JCN, 2007). Thus, these two regions serve as plausible candidates for the neural correlates of combinatorial processing during linguistic comprehension. However, as the interpretation of complete sentences involves a multitude of diverse processes, it is difficult to determine the full range of factors affected by these types of manipulations. In this magnetoencephalography (MEG) study, we investigated basic composition in a novel two-word paradigm, contrasting simple, unmodified nouns against those preceded by an adjectival modifier. Our goal was to assess what brain regions are involved in simple combinatoric processing, with the LATL and VMPC serving as initial regions of interest (ROIs). The spatial and temporal resolution of MEG should allow us to identify combinatorial effects located in these regions and determine their temporal dynamics. Design. 10 subjects were shown linguistic descriptions of an object and asked to judge whether a subsequent picture matched the preceding verbal description. The description was either unmodified, consisting of a single noun (e.g. "star"), or modified, with a color adjective preceding the noun ("red" then "star"). To control for low-level visual effects of the adjective, the unmodified nouns were preceded by stimuli that matched the adjectives in low-level visual properties – either novel symbol strings or unpronounceable consonant strings. In all conditions, activity was recorded at the noun ("star"). Results. An ROI analysis on distributed source activity during processing of the noun identified effects of modification in both the LATL (226-388ms post onset, $p < 0.001$) and VMPC (318-370ms, $p = 0.001$) using a cluster-based permutation test (10,000 permutations, Maris & Oostenveld, JNM, 2007). In both regions, we observed significantly more activity during processing of the modified noun compared to either the symbol or consonant strings (see Figure 1). A subsequent full-brain analysis confirmed these effects and did not readily suggest additional regions. Conclusion. Our results provide strong evidence that both the LATL and VMPC are crucially involved in basic linguistic combinatorial processes. The minimal combination of an adjective with a noun was sufficient to produce significantly more activity in these regions compared to the processing of an unmodified noun. In light of previous results linking the LATL to syntactic combination and the VMPC to semantic composition, the temporal ordering of our observed effects – increased LATL activity peaked at 250ms followed by increased VMPC activity peaking at 340ms – is consistent with the popular "syntax-first" processing model of linguistic comprehension (e.g. Friederici, TiCS, 2002).

10. Strategic decision-making during the interpretation of potentially ambiguous pronouns. *M. Grossman (1), C. McMillan (1), N. Ryant (1), D. Gunawadana (1), R. Clark (1).* (1) University of Pennsylvania, Philadelphia, US.

How do we assign a pronoun to its referent? Since pronouns are potentially ambiguous, we adapted a strategic decision-making approach for language. In our model, key elements include: Probability – associated with dorsolateral prefrontal cortex (dlPFC); executive resources – associated with dorsal IFC (dlFC); risk – associated with ventral inferior frontal cortex (vlFC); and an integrating role for inferior parietal cortex (IPC). Consider: "A client chased a waitress. He ran." Factors contributing to the interpretation of "he" as "a client" include: The probability of noun phrase (NP) meaning - waitresses are likely to be females, but clients are gender-neutral; executive resources - it is costlier to pronominalize a less prominent (the second NP) than a more prominent (the first NP) element of a sentence; and the risk of miscommunication if pronoun assignment is incorrect. Extensive pretesting identified 40 sentences that are ambiguous with respect to assigning a pronoun in a 2-word sentence to a referent in an antecedent 5-word sentence (Both NPs gender-neutral in half, eg. "A client chased a student. He ran"); 40 unambiguous stimuli where lexical content determines a preference for selecting the first (in half the sentences) or second NP (eg. "A priest chased a waitress. He ran"), and 40 sentences containing one gender-neutral and one gender-biased NP (the first NP was gender-biased in half the sentences, eg. "A priest chased a student. He ran"). Frequency-matched, randomly-ordered stimuli were presented sentence-by-sentence and were written to minimize prosodic biases. Subjects judged the NP corresponding to the pronoun by button press, as in a training session. Behavioral analysis of 12 young adults used a linear mixed effects regression model, with sentence ambiguity score (ranging 0-5, depending on gender bias, NP location, ambiguity of the NP combination, and pronoun) as a fixed factor, and subjects and items as random factors. Subjects selected a gender-biased noun more often as the level of ambiguity decreased ($t=14.89$; $p=0.00001$). fMRI modeled the event with the pronoun-containing 2-word sentence. Ambiguous-Unambiguous contrast showed bilateral IFC (BA 44/45), dlPFC (BA 46), and superior medial frontal (BA 8) activation (all clusters FDR-corrected $p \leq 0.05$). Other categorical contrasts emphasized other features of the model. Assigning each stimulus an ambiguity score, regression analysis related pronoun interpretation to bilateral IFC, dlPFC and IPC activation (Figure). These findings emphasize the role of a large-scale neural network during strategic decision-making about the interpretation of potentially ambiguous pronouns.

11. On the domain-specificity and domain-generality of the semantic system: semantic processing of pictures compared to words. *C. Esopenko (1), J. Cummine (1), G. E. Sarty (1), and R. Borowsky.* (1) University of Saskatchewan, Saskatoon, Canada.

We examined the semantic processing of objects presented in picture and word format in order to evaluate three models of semantic representation: an amodal semantic system, whereby stimuli are processed in the same central system regardless of the input modality (Caramazza et al., 1990); multiple semantic systems, which proposes that stimuli are processed in separate

sub-systems based on input modality (Shallice, 1988); and finally a hybrid graded semantics model that suggests both common and independent semantic systems based on input modality (Plaut, 2002). Previous neuroimaging research has supported the notion of a hybrid graded semantics model by showing both unique and shared regions of activation during the semantic processing of picture and word stimuli (Borowsky et al., 2005; Esopenko et al., submitted; Vandenberghe et al., 1996). Furthermore, recent neuroimaging research has shown a somatotopic-semantic organization in the fronto-central regions during the processing of action-related language (Esopenko, et al., 2008; Hauk, et al., 2004; Tettamanti et al., 2005). Objectives: The current experiment will compare how pictures and words differentially influence the processing of action-related language in the fronto-central regions, and how semantic processing is affected by the sensorimotor qualities of the object. Methods: Our experiment used functional magnetic resonance imaging (fMRI) to examine whether the fronto-central regions are organized somatotopically during an overt semantic generation task, with stimuli presented in either picture or word format that naturally involve either arm or leg interactions. The experiment consisted of 3 tasks: 1) A motor localization task, where the word "hand" or "foot" was presented on the screen in the MRI and participants were instructed moved the body part the word depicted; 2) A semantic generation task with picture stimuli, where a picture of an object (used by either their arm/hand or leg/foot) was presented on a screen and participants were instructed to verbally respond to "how they would use the object?"; and 3) A semantic generation task with word stimuli (using the same paradigm as described in the picture task). Sixteen participants completed the experiment, with 8 participants receiving 25 arm/hand stimuli (in both picture and word format) and 8 participants receiving 25 leg/foot stimuli. Shared (activation common to both tasks) and unique (activation specific to each task) activation maps were created comparing picture and word processing for both arm and leg stimuli. Results: Our results indicate that there are unique and shared regions of activation for pictures and words that differ across arm and leg stimuli, ultimately supporting the hybrid graded semantics model. Furthermore our results provide support for the somatotopic-semantic organization of the fronto-central regions, whereby the arm semantic generation tasks (across input modalities) activated mid-dorsal fronto-central regions, while leg semantic generation tasks activated the dorsal fronto-central regions. Conclusions: The current results provide evidence against strictly amodal or multiple semantics theories of semantic processing, but rather provide empirical support for the hybrid graded semantics model (Plaut, 2002). Furthermore, the results suggest that future theories of semantic processing must take into account both the input modality and body part the object represents.

12. Early and late Event Related Potentials components during semantic analysis correlate with phase resetting of ongoing oscillatory activity. *E. Brunetti (1), W. López (1), F. Aboitiz (1). (1) Pontificia Universidad Católica, Santiago, Chile.*

Even though Event Related Potentials (ERP) components are broadly used in neurolinguistic studies, the neural mechanisms underlying the appearance of these voltage fluctuations on the scalp are not well understood. Some evidence indicates that a mechanism of phase resetting of the ongoing oscillatory activity accounts for the appearance of early ERP components during sensory processing, but it is unclear if a similar process takes place during language analysis. In this work, we studied this possibility in electroencephalographic signals generated during a lexical decision task, (I) by assessing the conservation of the angular phase of oscillations across trials in the frequency domain, and (II) comparing, in the pre and post stimulus periods, the amplitude and spatial pattern of the scalp activity in specific frequencies. For this purpose, we firstly defined frequencies of interest based in the spectrogram of signals during the temporal window related to task solving. We found modulations in four frequency bands (delta, theta, alpha and gamma). Then, the stability of the angular phase across trials for each frequency of interest was computed in each electrode, and compared with a baseline period. Statistical significance of inter-trial phase synchrony (ITPS) values was assessed by computing statistics with shuffled trials of the original signal. Significant modulations of ITPS in delta, theta and alpha bands were evidenced. The temporal patterns of these modulations were compared with the temporal profile of early and late ERP components obtained. This analysis revealed relation between the modulations in all of these frequencies with early ERP components (i.e. N100-P100), while the modulation in delta band was related to late (i.e. N400-P600) components. It was computed the correlation between the values of ITPS for each frequency and the amplitude of evoked components across electrodes. In addition, it was analyzed the covariance across trials of the measures of dispersion of phase values (around the circular mean of all trials) in the peaks of evoked components with the amplitude and polarity of the raw signal in each electrode. All of these analyses showed a significant correlation between values of ITPS and the amplitude of the evoked components. The study in the time domain showed that the ERP computed from the signal filtered in theta and alpha bands resemble the polarity, amplitude and topography of early ERP components obtained from the raw signal, while that obtained in delta resemble the same variables in late components. Finally, latency corrected average of filtered signal showed a high similarity of the topography and amplitude of signals during baseline and post stimulus period. These results strongly suggest that the processes that modulate (disturb or synchronize) the phase of ongoing cortical oscillations in specific time windows could (I) modulate ERP amplitude, (II) be studied as mechanisms that explain language disturbances and (III) be exploited as mechanisms that improve semantic comprehension of language.

13. An Event-related Potential Investigation of Hemispheric Asymmetries in Sentence Comprehension. *Z. Qi (1), S. R. Jackson (2), and S. M. Gamsey (3). (1) Neuroscience Program, University of Illinois, Urbana-Champaign (2) University of Maryland (3) Department of Psychology, University of Illinois, Urbana-Champaign*

The brain hemispheres make different contributions to language processing. One recent finding is that the left hemisphere

actively predicts features of upcoming words based on semantic context, while the right hemisphere processes incoming words more passively (Federmeier, 2007). The current study extends these findings by examining hemispheric asymmetries in processing syntactic aspects of sentences, combining visual half-field methods with the concurrent measurement of event-related brain potentials (ERPs). The goal was to test whether the left hemisphere predicts the syntactic category of an upcoming word based on the structure of the sentence so far. Expectation was manipulated in two ways: 1) by using verbs that are more often followed by one kind of structure than another, and 2) by including or omitting an optional function word whose presence clearly predicted a particular sentence structure. In the sentence *The referees warned the spectators about shouting*, the spectators are the ones being warned, i.e., spectators is the direct object (DO) of warned. In contrast, in *The referees warned the spectators might shout*, someone unspecified is being warned about the spectators, and spectators is the subject of an embedded sentential complement (SC). The verb warned is used more often in sentences like the first one, so it has a "DO-bias", and when it is used in a sentence like the second one, the embedded verb might elicits longer reading times and a P600 in ERP waveforms, indicating a violation of expectation. In contrast, when sentences like these contain SC-bias verbs, there are no similar indications of difficulty (Garnsey et al., 1997; Osterhout et al., 1994). In this experiment, verb bias was manipulated and the embedded verb might was presented in either the left or right visual field (LVF or RVF), to tap into whether the right and left hemispheres both developed predictions based on the bias of the verb earlier in the sentence. In a second manipulation, the optional complementizer that was either included (*The referees warned that the spectators might shout*), which clearly predicted an embedded SC structure, or it was omitted. Participants read sentences presented word by word at the center of the screen except for the disambiguating auxiliary verbs (e.g. might), which appeared in either the LVF or RVF. Two aspects of the results support the idea that the left hemisphere predicts upcoming sentence structure but that the right hemisphere does not. The first was a larger P600 in response to the auxiliary, suggesting that participants did not expect a verb in that position, when the complementizer that was omitted, but only when the auxiliary was presented in the RVF ($p < .01$). The second was a larger late frontal positivity (LFP) in response to the auxiliary when it violated predictions based on verb bias, again only when presented in the RVF ($p < .05$). The LFP has recently been interpreted as indicating the cost of reanalysis associated with expectancy (Federmeier et al., 2007). Together, these findings provide support for the claim that the left hemisphere is more actively engaged in making predictions during language comprehension.

14. A temporal dissociation of semantic and syntactic parsing in on-line Chinese sentence comprehension: Evidence from Eye Movements and ERPs. *S. Wang (1), D. Mo (1), H.-C. Chen (2). (1) South China Normal University, Guangzhou, China (2) Chinese University of Hong Kong, Hong Kong, China.*

Reading comprehension involves a variety of complex processes, such as orthographic, phonological, semantic, and syntactic processing. From the psycholinguistic perspective, a central issue in the study of reading concerns whether different types of reading processes involve unique or shared cognitive mechanisms. Using a violation paradigm, this study investigated whether distinct patterns of semantic and syntactic parsing exist in on-line Chinese sentence comprehension. In two experiments, participants read sentences for comprehension. Stimuli were Ba/bei constructions, taking the form of NP1-ba/bei-NP2-VP, in which only transitive verbs could be used at the VP position. Three types of sentences were constructed: congruous sentences (CON), sentences with a semantic violation (SEM), and sentences with both semantic and syntactic violations (SEM+SYN). The SEM and SEM+SYN conditions were realized by substituting a semantically inappropriate transitive verb or a semantically and syntactically incongruent intransitive verb respectively for the correct transitive verb in the CON condition. Sentences in both anomalous conditions were matched in their degree of semantic plausibility. Experiment 1 observed participants' eye movements, while Experiment 2 recorded the ERPs elicited by the critical verbs. Experiment 1 showed that both types of violations could be detected immediately, with significant increases appearing in the first-pass reading time on the anomalous target verbs. Besides, while in the target region no detectable difference in early or late measures was found between the incongruous conditions, increased effects of violation were found in the post-target region on both early and late measures for the SEM+SYN condition relative to the SEM condition. Experiment 2 revealed that relative to their congruent counterparts, the critical verbs in the SEM and SEM+SYN conditions elicited a widely distributed N400 effect, with no detectable difference in amplitude between the latter two conditions. Furthermore, compared with the CON condition, the SEM and SEM+SYN conditions triggered a P600 effect, with the amplitude of the latter being more positive-going than that of the former over the whole scalp. In the later time window (i.e., 1000-1400ms), compared with the CON and SEM conditions, the SEM+SYN condition elicited a sustained positive potential over anterior and central sites. To summarize, both experiments demonstrated that Chinese semantic and syntactic processing are temporally dissociable, with both being initiated quickly but the former a little earlier than the later, as indicated by the fact that the introduction of syntactic violation did not influence the early semantic processing. Moreover, the ERP data revealed that the difference between the two violation conditions appeared 500ms after the onset of the critical verb, suggesting that readers did not have to wait until the post-target region to initiate syntactic processing.

15. Neural correlates of implicit and explicit conceptual combination. *W. W. Graves (1), J. R. Binder (1), R. Desai (1), L. L. Conant (1), and M. S. Seidenberg (2). (1) Medical College of Wisconsin, Milwaukee, US. (2) University of Wisconsin, Madison, US.*

Conceptual combination is the process by which meanings are derived from combinations of words. We studied this process using 3T fMRI by comparing noun-noun phrases that form a meaningful combination (e.g., "the lake house") to their reversed

forms, which do not ("the house lake"). One participant group (N = 23) performed a 1-back task in which they monitored for repetition of either word from the previous noun-noun phrase. Explicit semantic processing is not required for this task. A second group of participants (N = 19) explicitly judged whether each phrase was meaningful, not meaningful, or composed of nonwords. Stimuli were the same as for the first group but also included phrases comprised of nonwords. Phrases were chosen from a larger set normed for meaningfulness by a separate group of subjects. There were 200 phrases of each type. Several areas previously associated with semantic processing, including the left angular gyrus, posterior cingulate gyrus, and dorsomedial prefrontal cortex, were activated for meaningful compared to reverse phrases in the semantic judgment task but not the 1-back task. The single area activated for this condition across both tasks was the right supramarginal gyrus, though this activation was larger and included the right angular gyrus in the explicit semantic task. Across both tasks, the left parahippocampal gyrus, an area previously implicated in lexical semantics, responded more to high than to low-frequency words. This area was also activated when the meaningful and reversed phrases were compared to nonwords. Overall the results confirm previous findings and extend them to include a role for left parahippocampal gyrus in lexical (single-word level) semantics as distinct from combinatorial processing. The finding of activation in this area for higher frequency words across both tasks suggests that it may reflect automatic activation within the semantic network. There was also a marked effect of task on phrase-level comparisons, with activation for meaningful greater than reversed phrases extending into the right angular gyrus and including left angular gyrus and posterior cingulate cortex only for the task that required semantic judgment. This finding suggests that the degree of explicit semantic processing affects the depth of conceptual combination. These findings are compatible with and provide additional neuroanatomical constraint to theories positing a disposition for lexical semantic processing in areas of the left hemisphere, and a disposition for more holistic, combinatorial semantics in areas of the right hemisphere.

16. Down the garden path: ERP evidence for telicity effects on thematic role re-assignment. E. Malaia (1), R.B. Wilbur (2), C. Weber-Fox (3). (1) Purdue University, West Lafayette, US. (2) Purdue University, West Lafayette, US. (3) Purdue University, West Lafayette, US.

Languages encode events using a small set of perceptually-based semantic features which affect syntactic structure of the predicate – dynamicity, causativity, telicity (Van Valin, 2007). This limited feature set comprises an "event structure template", and research on their processing may provide a link to the biological basis of linguistic structures (Kemmerer, 2008). Telicity is often formulated as a semantic property of predicates/verbs: telic verbs have an inherent event end-point (catch, rescue); atelics refer to homogenous activities (tease, host). Optionally-transitive telics were shown to facilitate processing of internal arguments in garden-path sentences ("The actress awakened by the writer left in a hurry"), whereas optionally-transitive atelic verbs seem to incur higher processing load on subsequent words due to increased difficulty of assigning new thematic roles (O'Bryan, 2003; Malaia, Wilbur, Weber-Fox 2009). The question whether telicity is salient for processing unambiguously transitive clauses with thematic role re-assignment remained open. Our study examined such telicity effects on re-analysis of thematic roles assigned by transitive verbs in Reduced Relative Clauses (RRCs; "The actress chaperoned/spotted by the writer left in a hurry"), as compared to Unreduced Relative Clauses (URCs; "The actress who was chaperoned/spotted by the writer left in a hurry"). We hypothesized that telicity would facilitate thematic role re-assignment in transitive RRCs, but not in URCs. Event-related brain potentials (ERPs) were recorded from 20 English speakers as they read sentences in which the main verb was either telic or atelic. ERPs elicited by these verbs, the preposition "by" introducing the second argument (Agent), and the definite article preceding the Agent were compared in each clause type. ERPs in RRCs significantly diverged on the definite article preceding the Agent: the atelic condition had larger amplitude negativity at the N100 over anterior electrodes (p<0.025), possibly indicating higher processing load related to difficulty of thematic role re-assignment. RRCs induced garden-path readings such that the first argument could be plausibly interpreted as the Agent until "by". Processing differences following transitive telic and atelic verbs demonstrate that telicity is a salient cue for thematic role re-assignment. ERPs in URCs did not differ significantly. Although URCs also induced garden-path readings such that the part of the sentence preceding "by" could be interpreted as a complete relative clause, recovery from this garden-path did not require re-assignment of thematic roles. The data demonstrates that telicity is a salient cue for thematic role assignment in transitive clauses. We suggest that this effect is similar to the phenomenon of internal argument priming in unaccusative verbs (Friedmann, Taranto, Shapiro, & Swinney, 2008), and that both might be explained within event structure theory, which integrates verbal semantic features and thematic roles as structural positions (Ramchand, 2008).

17. ERP correlates of sentence-level semantics. L. Ferdinandino (1) and E. Zaidel (1). (1) University of California Los Angeles, Los Angeles, U.S.

The processing of lexical semantics in language comprehension has been associated with specific event-related potentials (ERPs), most notably the N400. In the present study, we directly compared the ERP correlates of word-level and sentence-level semantics by independently manipulating (1) thematic role assignment, (2) lexical semantics, and (3) sentence structure. We recorded ERPs from 24 participants while they read a pair of action-related sentences and compared their meanings. In the Syntactic condition, the two sentences in a pair contained exactly the same words, but the word order was always different. In the Lexical condition, the word order was maintained across the two sentences, but a single word was replaced by a new one. In half of the trials for each condition, the two sentences had congruent meanings; in the remaining trials the meanings were incongruent (Table 1). We also manipulated sentence structure (relative-clause vs. passive-voice). A bilateral,

negative-going component (NC) was larger for the Lexical condition compared to the Syntactic condition between 300 and 400 ms, reflecting the demands of processing a new word relative to a repeated one. The demands of processing a new meaning compared to a recently encountered one was reflected by a right-lateralized, positive-going component (PC), which, in both conditions, was larger for congruent than for incongruent trials in the 400-550 ms window. This result also indicates that, in both Lexical and Syntactic trials, the PC was associated to the building of a mental model for the second sentence that matched the one created by the first sentence. This, in turn, suggests that similar neurophysiologic processes underlie the later stages of semantic integration, whether the information refers to lexical semantics or to thematic-role assignment. The NC showed no effect of congruency for Lexical trials, but it was significantly larger for incongruent than for congruent Syntactic trials. This suggests that, in the Syntactic condition, thematic-role assignment was already under way in the 300-400 ms time window, and was being affected by the mental model generated by the first sentence. There was no significant interaction between Congruency and Sentence Structure for neither condition.

18. The Hemispheric Processing of Sarcastic Text. *L. Motyka Joss (1); S. W. Briner (1), B. McCarthy (1), S. Virtue (1). (1) DePaul University, Chicago, US.*

Sarcasm is a type of figurative language in which the intended message does not match the literal interpretation. Some theories of sarcasm comprehension propose that readers first extract the literal meaning of a text and then the intended, sarcastic meaning (e.g., Ivanko & Pexman, 2003), whereas other theories propose that both meanings of a sarcastic text are simultaneously activated (e.g., Giora, 1998). Research with other types of figurative language, such as metaphors, show that both literal and figurative meanings are activated in the right hemisphere and only literal meanings are activated in the left hemisphere (Anaki, Faust & Kravetz, 1998). To investigate this issue in more detail, we examined the roles of the left and right hemisphere during the processing of sarcastic text. In this study, 94 university students read 48 two-sentence texts. In these texts, the first sentence described an interaction between two characters (e.g., Alice watched as Sean completed his third helping of turkey and stuffing.). The second sentence contained a spoken statement from one character. In 16 of these texts (i.e., the sarcastic condition), the second sentence was sarcastic (e.g., She laughed, "You don't have much of an appetite today, huh?") to convey a specific message (e.g., hungry). In another 16 texts (i.e., the literal condition), the second sentence relied on literal criticism to convey a message (e.g., She laughed, "I think you've tried every dish on the table!"). In a final set of 16 texts (i.e., the neutral condition), a statement that was not related to the previous interaction was described (e.g., She laughed, "Are you ready to watch the football game now?"). After reading these texts, participants made lexical decisions to target words that were related to the intended meaning of the sarcastic text (e.g., hungry). Using a divided visual field paradigm (Bourne, 2006), targets were presented for 176 ms to either the left visual field-right hemisphere (lvf-RH) or the right visual field-left hemisphere (rvf-LH). Forty-eight filler items with corresponding non-word targets were also presented to avoid participant response bias. Response times to target words during the lexical decision task were recorded. To determine the amount of activation in the hemispheres during the processing of sarcastic text, facilitation effects were calculated by subtracting the response times in the sarcastic or literal condition from the response times in the neutral condition. Facilitation effects were entered into a 2 (visual field-hemisphere: left visual field-right hemisphere or right visual field-left hemisphere) by 2 (condition: sarcastic or literal) repeated measures ANOVA. We found a significant interaction between visual field-hemisphere and condition, $F(1,92) = 4.83, p \leq .05$. Follow up *t* tests showed that in the left hemisphere, literal targets received greater facilitation than sarcastic targets, $t(92) = -2.85, p \leq .05$, however, in the right hemisphere literal and sarcastic target facilitation did not differ, $p > .05$ (see Figure 1). These findings suggest that sarcastic language is processed differently in the right and left hemispheres, and support previous findings (Anaki et al., 1998) showing a right hemisphere advantage for processing figurative language.

19. An fMRI investigation of working memory involvement in discourse anaphors processing. *A. Almor (1) J. May (1) T. W. Boiteau (1). (1) University of South Carolina, Columbia, SC, US.*

Anaphoric reference is an important part of coherent discourse, and discourse anaphors can take many forms. Although much is known about the linguistic and behavioral aspects of anaphoric processing, not much is known about its neural underpinnings. Due to the importance of repeated reference to discourse coherence, the better understanding of the neural basis of anaphor processing is crucial for the understanding of the brain basis of language more broadly. The current study thus investigated the neural basis of one central property of anaphoric processing, which is that anaphoric references to salient antecedents tend to employ more general expressions than the antecedent. Such anaphors frequently assume a pronominal form but sometimes also take the form of a general category term. For example, in the sample discourse below, the category anaphor "the bird" is used to refer to the category member antecedent "the robin." What the boy chased was the robin. For a short time, the bird enjoyed the chase. One important finding in behavioral studies of category anaphors is the Inverse Typicality Effect (ITE). The ITE is the slower reading of a category anaphor (e.g., the bird) when referring to a salient antecedent, when that antecedent is a typical member of the category (e.g., robin) rather than an atypical one (e.g., ostrich). This effect was previously argued to reflect increased working memory load caused by interference between the category anaphor and a typical member antecedent before they are integrated. This interference is related to the greater semantic overlap between the anaphor and the antecedent in the typical rather than the atypical case. The current study tested this claim directly by examining the neural activation associated with the ITE. We used functional Magnetic Resonance Imaging (fMRI) to measure the brain activation of participants as they read short discourses presented one sentence at a time. Critical

items were similar to the sample discourse above. The first sentence in the critical items used a wh-cleft construction to focus the target category member referent. The second sentence included in the subject position a category anaphor referring back to that antecedent. In the typical condition, the category member antecedent in the first sentence was a typical member of the category anaphor and in the atypical condition it was an atypical member of that category. Consistent with working memory involvement, we found that the typical condition led to greater activation than the atypical condition in left Middle Frontal Gyrus, Inferior Frontal Gyrus, Precentral Gyrus (no regions that showed greater activation in the atypical than the typical condition). Thus, our results provide direct support for the previously hypothesized role of working memory in the ITE. To our knowledge, these results are unique in providing fMRI-based support for a theoretical claim about processing discourse reference.

20. Neural Basis of Abstracted Meaning. *R. Anand (1) M. A. Motes (1) M. J. Maguire (1) P. S. Moore (1) S. B. Chapman (1) J. Hart (1). (1) The University of Texas at Dallas, Dallas, US.*

A large body of literature has supported the claim that memory for abstracted meaning, commonly referred to as gist, differs from memory for details or specific content. Fewer studies, however, have investigated the neural basis of these two forms of information processing. This study examined these processing differences in abstracted meaning versus details using functional magnetic resonance imaging (fMRI). Participants ($n=7$, age 20-30 years) judged whether a given statement corresponded to abstracted meaning or details conveyed in Norman Rockwell digital pictures (pretested for consistent detail and abstract meaning judgments) while fMRI data were collected. Each picture was paired with statements that conveyed congruent abstracted meaning or described details that were present in the picture and foil statements that conveyed incongruent abstracted meaning or described details that were not present. For the purpose of counterbalancing, the congruent abstracted and detail statements of one picture were used as foil statements for others. Thus, a total of 4 statements were paired with each picture. Participants worked through two runs, 40 trials and 7 minutes per run. Participants indicated, via MR compatible button-boxes, whether the sentences accurately described the abstracted meaning or details of the picture. EPI fMRI data (TR = 2000 ms; TE = 30ms; FOV = 220 mm AP \times 144mm FH \times 220mm RL; flip angle = 70°; matrix resolution = 64 \times 64; slice thickness = 3 mm; 36 axial orientation slices) were collected on a Philips Achieva 3T scanner equipped with an 8-element sense head coil. The fMRI data were deconvolved using linear regression modeling to obtain voxel-wise estimates of task-related BOLD signal-change. The differences between estimates for the abstracted meaning and detail conditions were then compared. Greater activation for the abstracted meaning condition was observed primarily in left supramarginal, bilateral superior frontal along the anterior medial aspect, and bilateral inferior frontal brain regions. Greater activation for details was observed primarily in bilateral inferior and superior parietal, dorsolateral prefrontal and lateral occipital complex regions. These results show that assimilating abstracted meaning from complex pictures elicited the engagement of different brain regions than searching for details. The regions differentially involved in processing abstracted meaning have been previously associated with comprehension, processing abstract words, reasoning, and working memory. The regions differentially involved in searching for details have been previously associated with visual search, processing concrete words including object processing, and attention allocation. Overall, these findings have both clinical and theoretical significance. Given that processing of abstracted meaning is differentially impaired compared to details in several clinical populations including traumatic brain injury, attention deficit hyperactive disorder, and early Alzheimer's disease, the neural markers identified in this study can be used to examine alterations in pattern and degree of regional brain activation in these populations that correspond to behavioral changes in processing. Additionally, the findings inform theories about representation of abstracted meaning versus details for complex information.

21. Electrophysiological evidence for morphological rule application in correct word-forms. *R. Lebib (1), A. Krott (1). (1) University of Birmingham, Birmingham, United Kingdom.*

A critical issue for understanding language processing in the brain is whether linguistic rule application is subserved by a distinct neural substrate. One of the evidence supporting such a hypothesis comes from studies employing electroencephalographic measurements during the processing of rule misapplication, i.e. when the linguistic rule is violated. The typical effect of rule misapplication is a left anterior negativity (LAN). This evidence is, however, inconclusive because it might reflect processes caused by the violation itself, such as error handling, rather than the non-application of rules per se. Previous LAN studies have also not addressed the dissociation between high and low frequency regular forms observed behaviorally. If high frequency regular forms are accessed via full-form activation, rule processes might be activated only for low frequency regular forms and not for high-frequency regular forms. The present study seeks for the first time electroencephalographic evidence for rule processing by presenting only correct forms and avoiding the disadvantage of violation paradigms. In addition, it investigates whether electrophysiological responses can confirm the behavioral dissociation between high and low frequency regular forms, by presenting both high and low frequency forms for both regular and irregular forms. We presented high-frequency and low-frequency correct regular and irregular German participles embedded in sentences. These participles were formed by adding a prefix *ge-* to a verb stem plus either the suffix *-(e)t* (*ge-glaub-t* 'believed') or the suffix *-(e)n* (*ge-fahr-en* 'driven'). Of the two suffixes, *-(e)t* is understood as being the regular one and *-(e)n* the irregular one. This distinction is based on the suffixes' productivity in novel formations. Regular and irregular German participles had equal phonological complexity and they were matched for length, frequency of lemmas and frequency of full-forms on both frequency levels. Electrophysiological responses revealed distinct patterns for the two types of German participles: compared to irregular participles, regular

participles elicited a negative-going response over the left tempo-frontal scalp area peaking at around 400 ms after stimulus onset. This effect was present for both high and low frequency words, although low frequency regular words elicited an additional centre at posterior sites. Our findings support the assumption that regular and irregular participles are handled by at least partially distinct neural substrates during word processing. Our results are therefore rather in accordance with dual-mechanism models of morphological processing that assume a separate mechanism for regular inflection. However, because a left tempo-frontal negativity was present regardless of the participles' frequency, the cerebral structures associated with rule-based mechanisms appears to be activated independently from the mode of lexical access (i.e. decomposition or full-form activation). We therefore argue for a parallel route model, in which a separate rule mechanism is activated independently of lexical access and in which inflected words can be processed by more than one route in parallel. Together with previous electrophysiological studies employing violation paradigms, our findings suggest that left anterior negativities most likely reflect neural processes that underlie the licensing stage of the word decomposition/recognition process.

22. Intraindividual response time variability during on-line sentence comprehension in left- and right-brain-damaged patients. *C.M. Grindrod (1), T.M.J. Loucks (1), and J.J. Sosnoff (1). (1) University of Illinois at Urbana-Champaign, Champaign, US.*

Most studies investigating on-line language processing in patients with acquired brain damage have focused on mean response time (RT) differences between patients and control subjects. Any RT variation within individuals has only been minimally considered or viewed as measurement error. Recently, intraindividual variability in cognitive processing speed has been suggested as a marker of overall neurological health (MacDonald et al., 2006). Consistent with this claim, increased intraindividual variability has been observed after acquired brain damage (Stuss et al., 2003, 2005). While brain-damaged patients clearly exhibit greater RT variability in nonlanguage tasks, it is unknown whether they exhibit similar variability in language processing tasks. Thus, the goal of the current study was to investigate the effect of left and right hemisphere brain damage on mean RT and RT variability during on-line sentence comprehension. Left-brain-damaged (LBD) aphasic patients, right-brain-damaged (RBD) nonaphasic patients and age- and education-matched control subjects participated in a cross-modal lexical priming experiment. Subjects first listened to sentences ending in ambiguous words (e.g., While digging the hole, he dropped the SPADE.) or matched sentences ending in unambiguous words (e.g., While digging the hole, he dropped the BOX.). They then made a lexical (i.e., word/nonword) decision on a visual target word that was either semantically congruent (e.g., shovel) or incongruent (e.g., cards) with the sentence context while RT and accuracy were recorded. Brain-damaged patients were expected to have longer RTs and increased intraindividual variability relative to controls. In addition, if individuals were sensitive to the sentence context in resolving ambiguity, they were expected to produce faster RTs and less intraindividual variability in congruent than incongruent contexts. Unexpectedly, only LBD patients had significantly slower mean RTs than controls; however, both brain-damaged groups exhibited significantly more intraindividual variability than controls. More interestingly, LBD patients, unlike controls, produced slower mean RTs and greater variability in congruent than incongruent contexts. In contrast, RBD patients produced faster mean RTs in congruent than incongruent contexts, but unlike controls, exhibited similar variability in the two contexts. These findings demonstrate that increased RT variability during on-line language processing is indeed a characteristic of brain-damaged patients. Moreover, patterns of mean RT and variability may provide a means to dissociate patients with left- or right-brain damage.

23. The dual-stream model of the functional anatomy of language: Challenges posed by Wernicke's aphasia. *H. Robson (1), K. Sage (1), R. Zahn (1), M. Lambon Ralph (1). (1) The University of Manchester, UK*

Recent evidence from functional neuroimaging indicates that speech processing consists of two streams. A unilaterally organised dorsal stream in the left hemisphere, responsible for producing phonemically organised speech and a bilaterally organised ventral stream responsible for speech comprehension (Hickok & Poeppel, 2007). Such a model indicates that bilateral damage is necessary to produce a phonemically based comprehension impairment (Rogalasky et al., 2008) and therefore unilateral lesions only disrupt comprehension due to impaired semantic processing. This theory goes against Wernicke's original hypothesis, that Wernicke's aphasia arose due to damage to 'sensory images' for words without an impairment to intelligence (Wernicke, 1874), and subsequent clinical observations that Wernicke's aphasia arises primarily due to damage to cortical areas attributed to phonological processing. Seemingly conflicting theories may arise due to confusion over terminology referring to perceptual processing. Here the term acoustic processing is confined to early spectrotemporal analysis of the acoustic stream and phonological processing refers to the extraction of word forms from the acoustic stream in a system of abstract phonological units. This research investigated the degree to which phonological or semantic processes were responsible for the comprehension impairment in Wernicke's aphasia. Data are presented from six patients with a behavioural profile of Wernicke's Aphasia, diagnosed through the Boston Diagnostic Aphasia Examination (Goodglass et al., 2001), and with corresponding MRI or CT scans showing lesions to the temporoparietal area. Method: A battery of assessments was undertaken which investigated comprehension over different modalities. The battery consisted of four tests all with the same target items, a spoken word to picture match and written word to picture match task and a pictorial and written version of a test of semantic association. This allowed for comparison between assessments. Results: Both phonological and semantic impairments were found in the group as a whole and one patient showed an isolated phonological impairment. The results showed a significantly greater impairment accessing semantic representations from the spoken than written modality and a significantly greater impairment identifying semantic relationships in the written than pictorial modality.

The patients differed in the degree of phonological and semantic involvement creating systematic variation within the group. Discussion: A disruption to phonological processing was sufficient to create the comprehension impairment in Wernicke's aphasia. In the majority of cases both semantic and phonological impairments contributed to the overall comprehension impairment. Conclusions: Left hemisphere unilateral lesions are sufficient to cause a comprehension impairment due to disrupted phonological processing.

24. ERPs and contextual semantic discrimination hypothesis: N400 deficits of different degrees of congruency in probands and first degree relatives from multiplex schizophrenia families. A. Ibáñez

(1,2), E. Hurtado (1), A. Lobos (1), J. Escobar (1), N. Trujillo (3), and J. Decety (5) *Subliminal presentation of other-faces (but not self-faces) primes semantic processing of painful expressions.* 1. Neuroscience Laboratory, University Diego Portales, Santiago, Chile 2. Institute of Cognitive Neurology (INECO), and Career of the National Scientific and Technical Research Council (CONICET), Argentina 3. Neuroscience Group, University of Antioquia, Medellín, Colombia 4. P. Catholic University of Chile, Santiago, Chile 5. Department of Psychology, Department of Psychiatry, and Center for Cognitive and Social Neuroscience, The University of Chicago, US.

Endophenotypes is one emerging strategy in schizophrenia research that is being used to identify the functional importance of genetically transmitted, brain-based deficits present in this disease. Currently, event-related potentials (ERPs) are timely used in this search. Recently, we report the first evidence of N400 deficits (significantly reduced N400 amplitude for congruent categories) in probands and first degree relatives in a picture semantic-matching task suggesting a probable contextual semantic deficit [Guerra, S, Ibáñez, A, Bobes, A., Martin, M et al. (In press). *Brain and Cognition*, 10.1016/j.bandc.2009.02.004]. In order to directly test the hypothesis of contextual semantics deficits as a probable endophenotype, unaffected first-degree relatives of patients, DSM-IV diagnosed schizophrenia probands, and control subjects, matched by age, gender and educational level performed an contextual task with four degrees of contextual congruency, previously reported by our team [Ibáñez, A., Lopez, V., Cornejo, C. (2006). *Brain and Language*, 98, (3), 264-275.]. Results support the idea of N400 contextual deficits in semantic integration as possible endophenotype candidate: Compared to control, N400 from relatives only discriminate congruent of incongruent target, but not partially contextual incongruent targets. Compared to controls and relatives, N400 from probands failed to discriminate partially and totally incongruent categories from congruent trials. These results demonstrate an electrophysiological deficit in contextual semantic discrimination in clinically unaffected first degree relatives and probands with schizophrenia from multiplex families, confirming a possible use of this marker as endophenotype.

25. An fMRI study on m-sequence modulated speech comprehension. S. Koyama, H. Takeichi, A. Terao, F. Takeuchi. *JST, Kawaguchi, Japan.*

In an attempt to develop a technique for objective assessment of the unifying process of verbal comprehension in a short time, independent of syntactic or phonemic performance and vocabulary. We have developed a novel technique to access speech comprehension using EEG and MEG by modulating speech sound using m-sequence (maximum length shift register code) (Takeichi, Koyama, Matani, and Cichocki, 2007, *Neuroscience Research*, 57:314-8). Using this technique, we first replaced parts of the continuous speech sound stimulus with short temporal gaps of variable durations according to a m-sequence which is a pseudorandom binary number (0 or 1) sequence. In the context of speech comprehension, we assumed that signals acquired during and after each of the silent intervals (gaps) correspond to neural computations used to bridge the gaps in the stimuli for comprehension of the narrative, depending on the availability of contextual information. Subjects (all Japanese, right-handed) were listening to modulated speech. Time-locked changes elicited by the modulated speech in the EEG signals were detected by computing a cross-correlation function between the modulator m-sequence and the EEG signals. Independent component analysis (ICA) was then applied to the correlation functions to examine components specific to verbal comprehension. As a result, we identified a cross-correlation peak, which was observed with a 400-ms delay between the m-sequence and the EEG record, exclusively for the comprehensible speech sound. Thus it was shown that a 1-min long EEG signal is sufficient for the assessment of speech comprehension. In an attempt to search neural correlates of this ICA component we performed functional magnetic resonance imaging (fMRI) experiment comparable to our EEG experiment. A non-integer alternating blocked factorial design was used (23 Japanese, right-handed) with time reversal and m-sequence modulation as factors. Contrasting brain activation between non-modulated forward (comprehensible) and reversed (incomprehensible) speech, revealed that the left temporal cortex along the superior temporal sulcus (STS; BA21 and BA39), left middle frontal gyrus (BA6), and right inferior temporal gyrus (BA21) were activated in response to comprehensible speech. Contrasting non-modulated and modulated speech stimuli revealed that the left temporal cortex (BA21 and BA39), parahippocampal gyrus (BA34), posterior cingulate (BA23), caudate, thalamus, and right superior temporal gyrus (BA38) were activated in response to non-modulated speech. Contrasting modulated forward comprehensible and reversed speech revealed that the right inferior frontal gyrus (RIFG; BA44/45) was activated in response to comprehensible speech. Contrasting modulated and non-modulated speech stimuli showed that the left inferior parietal lobe (LIPL, BA40) was activated by modulated speech. Estimated scalp projection of the component correlation function for the corresponding EEG data (Takeichi et al., 2007) showed leftward posterior dominance, consistent with a signal source in the LIPL. The LIPL, reported to be associated with verbal working memory and functioning of the phonological loop, might be over activated to compensate missing speech information in the modulated speech.

26. A new approach to investigating the functional specificity of language regions in the brain. E. Fedorenko (1), and N. Kanwisher (1). (1) MIT, Boston, US.

What brain regions are involved in language processing, and how functionally specialized are they? Functional neuroimaging work has identified a large number of language-sensitive brain regions, extending well beyond the classical language network (e.g., Geschwind, 1970). However, this work has found little evidence for functional specialization of these regions either for language per se (versus other cognitive processes), or for specific aspects of language processing (see e.g., Vigneau et al., 2006, Lindenberg et al., 2007, for recent meta-analyses). This picture is inconsistent with the findings from decades of neuropsychological investigations of brain-damaged patients, who sometimes show highly selective linguistic deficits (see e.g., Caramazza et al.'s work). We hypothesize that the lower degree of functional specialization observed in neuroimaging studies may result from the blurring of functional activations entailed in the traditional group-averaging approach used in virtually all imaging studies of language. We advocate an alternative approach, which circumvents problems of inter-subject variability (e.g., Tomaiuolo et al., 1999; Juch et al., 2006; Amunts et al., 1999; Fischl et al., 2007), in which language regions are defined functionally in individual subjects (e.g., Saxe et al., 2006). Our functional localizer task – in which subjects read sentences, word lists, or pronounceable nonword lists – robustly identifies a set of language-sensitive regions, including one or more left temporal candidate language regions (CLRs) in over 90% of subjects, and one or more left frontal CLRs in approximately 75% of subjects, in just 15-20 minutes of scanning (across two different tasks and sets of materials; Experiments 1-2). Experiment 3 further shows that these CLRs are modality-independent, responding similarly to linguistic materials presented visually vs. auditorily. The ability to identify a set of modality-independent language-sensitive regions in individual subjects enables us to investigate in detail the functional profiles of each of these regions, by measuring their responses to various linguistic and non-linguistic tasks. Experiment 4 uses functionally-defined CLRs to test the hypothesis that language and general working memory (WM) rely on overlapping brain regions. In each participant we identified a set of CLRs, and then examined these regions' responses to three tasks: (1) a sentence comprehension task (involving structurally easier/harder sentences), (2) an arithmetic task (involving additions with smaller/larger numbers), and (3) a spatial WM task (involving easier/harder spatial integrations). The CLRs responded strongly to the sentence comprehension task, but showed no response to either the arithmetic task or the spatial WM task. These results argue against the strongest version of the claim that language and general WM rely on the same brain regions. Future work will be aimed at evaluating the response of functionally-defined CLRs to (1) tasks in other domains, and (2) linguistic tasks taxing different aspects of language (e.g., conceptual, lexical-level, syntactic, and pragmatic processing).

27. Combining functional and anatomical connectivity reveals brain networks for auditory comprehension. D. Saur (1,3), W. Mader (1,4), Susanne Schnell (2,3), P. Kellmeyer (1,3), D. Kümmerer (1,3), D. Feess (1,4), B. Schelter (4), C. Weiller (1,3). (1) Department of Neurology (2) Department of Diagnostic Radiology, Medical Physics, (3) Freiburg Brain Imaging all University Medical Center Freiburg, Germany (4) Freiburg Center for Data Analysis and Modeling, University Freiburg, Germany.

In auditory language comprehension, two major processing steps may be distinguished: analysis of sound structure (phonological processing) and meaning (semantic processing). To investigate functional and anatomical connectivity between key regions involved in both processing routines, we combined directed partial correlation (dPC) on functional magnetic resonance imaging (fMRI) data with a diffusion tensor based probabilistic tractography method. Phonological processing, defined by contrasting listening to sound preserved pseudo speech with sound disturbed reversed speech, activated five left hemisphere regions in the superior temporal gyrus (STG), premotor and prefrontal cortex. Among these regions, dPC analysis identified the posterior STG as the central relay station by demonstrating an interaction with all other network nodes. Tractography showed that functional connectivity between temporal and premotor nodes is mediated by a dorsal pathway via the arcuate and superior longitudinal fascicle. In contrast, semantic processing, as defined by contrasting listening to meaningful speech with meaningless pseudo speech, involved five homotopic regions in the left and right hemisphere including the anterior and posterior middle (MTG) and inferior temporal gyrus as well as prefrontal cortex. Central relay stations identified by dPC were in the left posterior MTG and the orbitofrontal cortex as well as in the right anterior MTG. In both hemispheres, tractography revealed that functional connectivity between temporal and prefrontal nodes is conveyed by a ventral route via the extreme capsule. In addition, strong interhemispheric interactions between homotopic nodes were mediated via distinct commissural fibers. These findings demonstrate how phonological and semantic processing are instantiated in functionally interacting and anatomically interconnected large-scale brain networks and how specific network components are preferentially involved in both processing routines. This type of analysis should be applied to patients with focal brain lesions, e.g. due to ischemic stroke. It would be of interest to see how damage to particular network components alters the network structure, or, depending on the lesion, how well the functional deficit might be predicted by these networks.

28. Neural development of networks for audiovisual speech comprehension. A.S. Dick (1), A. Solodkin (1), and S. Small (1). (1) The University of Chicago, Chicago, US.

Introduction. Visual information from a speaker's lips and mouth accompanies everyday speech, enhancing comprehension for both adults and children. Although sensitivity to visual speech appears early, children's ability to benefit from it improves into late childhood or early adolescence. Previous studies with adults suggest that a network including posterior inferior frontal and ventral premotor regions (IFGOp/PMv), supramarginal gyrus (SMG), posterior superior temporal gyrus (STGp), planum

temporale, and posterior superior temporal sulcus (STSp) contribute to audiovisual speech comprehension (Campbell, 2008 for review). The extent to which the neurobiological substrate in the child compares to the adult is unknown. In particular, developmental differences in the network for audiovisual speech comprehension could manifest through the incorporation of additional brain regions, or through different patterns of effective connectivity, or both. In the present study we used fMRI and structural equation modeling (SEM) to characterize the developmental changes in network interactions for audiovisual speech comprehension. Method. Twenty-four adults and nine children (8-11-years) participated. fMRI was performed during two passive story listening conditions separated by a baseline fixation: (a) Audiovisual speech (AV) and (b) Auditory-only speech (A). Results. In both children and adults, AV activated a similar fronto-temporo-parietal network of regions known for their contribution to speech production and perception. However, the SEM network analysis revealed age-related differences in functional interactions among these regions. In particular, the influence of IFGOp/PMv on SMG differed across age groups during AV, but not A (Figure 1). This functional pathway might be important for relating motor and sensory information used by the listener to identify speech sounds. Further, its development might reflect changes in the mechanisms that relate visual speech information to articulatory speech representations. Specifically, although children are sensitive to visual speech, their audiovisual network does not appear to be adult-like, and might limit their ability to integrate the information provided by the visual signal into the comprehension process. We postulate that developmental experience producing and perceiving speech leads to increasingly precise and predictive motor speech representations.

29. Mapping cortical activations to sentence comprehension with a controlled visual/auditory matching task. G. A. Stefanatos, A. DeMarco, M. S. S. M. Bermo, C. J. Conklin, F. Mohamed, and S. Faro. (1) Temple University, Philadelphia, US.

Many functional magnetic resonance imaging (fMRI) protocols have been developed for mapping language comprehension. Substantial variations in design have yielded significant differences in the resulting patterns of activation and lateralization. Many of these paradigms are inappropriate for clinical investigations of language organization because: 1) they lack of an overt, easily measured response to monitor compliance and response accuracy; 2) they do not utilize comparable active nonlinguistic control tasks; 3) situational contexts differ significantly between verbal and nonverbal tasks; and/or 4) paradigms are often not appropriate across a broad age range or cognitive/linguistic levels. Here, we describe the development and preliminary results using a sentence comprehension-picture matching task designed to overcome these limitations. fMRI BOLD signals were measured in 17 neurotypical Temple University undergraduate students using a Siemens 3-Tesla scanner. Participants were simultaneously presented with a visual and an auditory stimulus and were asked to indicate by button press whether what they heard matched what they saw (yes/no). In a verbal condition, participants heard active canonical sentences (e.g., "the boy pushes the dog") and were asked to decide whether or not the sentence matched the accompanying picture. In the nonlinguistic control task, participants heard a sequence of 4-5 tones alternating in pitch (e.g., high-low-low-high) and were shown pictures depicting a linear array of dots varying in height (high vs. low). They were asked to indicate whether or not the tonal pattern matched the variations in the visual array. The two tasks were interleaved in seven 24-second blocks. Group activation maps revealed a strong left hemisphere asymmetry. Sentence processing activated traditional left hemisphere perisylvian auditory and language regions including superior temporal gyrus (BA 22 & 41) and transverse temporal gyrus, extending anteriorly to temporal polar regions and posteriorly to angular gyrus. Activations were also evident in middle temporal gyrus and fusiform gyrus which have been implicated in lexical-semantic processing and multimodal processing. Parahippocampal gyrus and visual cortex were activated presumably in relation to perceiving and encoding the complex visual information presented during the task. Activations in the right hemisphere were more limited, involving fusiform gyrus, parahippocampal gyrus and auditory areas of superior temporal gyrus. Performance accuracy did not differ significantly between the linguistic and nonlinguistic tasks (96% and 97% respectively), but reaction times to sentences were ~100 ms faster. Hemispheric lateralization in individual activation maps was correlated with estimates of cerebral dominance for language indexed by the fused word dichotic listening task, a behavioral measure that correlates highly with the results of Wada tests. Overall, this sentence comprehension task yielded expected asymmetries of language lateralization in most but not all neurotypical controls. Regions activated in the left hemisphere involved a network that has been linked to auditory, phonological and lexical-semantic processing of sentences in prior imaging studies. Areas involved in auditory and visual processing, audiovisual integration and memory encoding were activated bilaterally. Design features and the relative ease with which the task is performed suggests it may be worthwhile to evaluate in clinical populations. Comparisons with currently used clinical tasks are discussed.

30. Performance of sentence processing depends on multimodal mental simulation and related neuronal coupling. H.M. Mueller (1), and S. Weiss (1) and G. Rickheit. (1) Center of Excellence "Cognitive Interaction Technology", University of Bielefeld, Germany

With regard to meaning constitution, performance is consistently better for sentences with a concrete meaning according to several measures such as memorizing, recall and comprehension [e.g., 4,5,6], recognition and syntactic manipulations [e.g., 2, 5], and different levels of text processing [e.g., 8]. One of the most critical elements determining concreteness and thus facilitating sentence comprehension is the use of visual mental simulation (imagery) [e.g., 3,8]. In addition, other sensory-motor simulations, bodily states and situated action seem to contribute to sentence comprehension [e.g., 1]. With regard to meaning constitution, performance is consistently better for sentences with a concrete meaning according to several measures such as

memorizing, recall and comprehension [e.g., 4,5,6], recognition and syntactic manipulations [e.g., 2, 5], and different levels of text processing [e.g., 8]. One of the most critical elements determining concreteness and thus facilitating sentence comprehension is the use of visual mental simulation (imagery) [e.g., 3,8]. In addition, other sensory-motor simulations, bodily states and situated action seem to contribute to sentence comprehension [e.g., 1]. In this study, comprehension of sentences with either a strong concrete or abstract meaning were investigated by means of behavioral data analysis (rating, choice reaction time) and the recording of electrical brain activity (electroencephalogram, EEG). In the first experiment, we presented concrete and abstract sentences auditorily or visually to the participants while they had to perform a semantic judgment task. Behavioral results demonstrated a higher mean error rate and a longer reaction time for the processing of abstract sentences. Specifically, processing sentences, which contained only a single modality (either seeing or hearing something) showed faster reaction times than those dealing with two different simulation modalities (seeing and hearing something). The second experiment showed that the modality of sentence presentation (e.g., auditory) interfered with the respective mental simulation during sentence processing (e.g., hearing the verb seeing vs. reading the verb listening). A third experiment was performed to assess the neuronal EEG correlates of multiple mental simulations, which have to be integrated somehow in the brain in order to fulfilling environmental requirements and initiating appropriate behavior [7]. One hypothesis raised in the neurosciences that provides a possible solution to this "binding-problem" is the temporal correlation hypothesis. EEG data were analyzed in the light of this hypothesis. Central issue was the relation of linguistic processing to in- and decreased neuronal cooperation of brain oscillations in various frequency bands. Spectral coherence analysis of the EEG signals was performed with adaptive, bivariate auto-regressive moving average models (ARMA) in order to evaluating the dynamics of functional relationships between signals associated with language processes. The concreteness of a sentence correlated with the height and topographic distribution of EEG coherence within the theta (4-7 Hz) and the beta frequency band (13-18 Hz) indicating an increase of participating neuronal resources as a function of the occurrence of mental simulations. Taken together, these results strongly point at multimodal mental simulation influencing the speed and quality of sentence comprehension and correlating with the synchronization of the underlying neuronal networks. References [1] Barsalou, L.W. (2008). *Ann Rev Psychol*, 59: 617-645. [2] Begg, I. & Paivio, A. (1969). *J Verb Learn Verb Behav*, 8: 821-827. [3] Holcomb, P.J., Kounios, J., Anderson, J.E. & West, W.C. (1999). *J Exp Psychol Learn Mem Cogn*, 25: 721-742. [4] Holmes, V.M. & Langford, J. (1976). *J Verb Learn Verb Behav*, 15: 559-566. [5] Moeser, S.D. (1974). *J Verb Learn Verb Behav*, 13: 682-697. [6] Paivio, A. (1991). *Can J Psychol*, 45: 255-287. [7] Weiss, S. & Müller, H.M. (2003). *Brain Lang*, 85: 325-343. [8] Wipplich, W., Mayer, A.K. & Mecklenbräuer, S. (1991). *Schweiz Z Psychol*, 50: 268-282.

31. Topographical Functional Connectivity Pattern in the Perisylvian Language Networks, HD Xiang (1), HM Fonteijn (1,2), DG Norris (1,3), P Hagoort (1,4), (1) Radboud University Nijmegen, Donders Institute for Brain, Cognition and Behaviour, Nijmegen, The Netherlands (2)Helmholtz Institute, Utrecht University, Utrecht, The Netherlands (3)Erwin L. Hahn Institute for Magnetic Resonance Imaging, Essen, Germany (4)Max Planck Institute for Psycholinguistics, Nijmegen, The Netherlands. We performed a resting state functional connectivity study to investigate directly the functional correlations within the perisylvian language networks by seeding from three subregions of Broca's complex (pars opercularis, pars triangularis and pars orbitalis) and their right hemisphere homologues. A clear topographical functional connectivity pattern in the left middle frontal, parietal and temporal areas was revealed for the three left seeds. This is the first demonstration that a functional connectivity topology can be observed in the perisylvian language networks. The results support the assumption of the functional division for phonology, syntax and semantics of Broca's complex as proposed by the MUC (Memory, Unification and Control) model and indicated a topographical functional organization in the perisylvian language networks, which suggests a possible division of labor for phonological, syntactic and semantic function in the left frontal, parietal and temporal areas.

32. Semantic size comparisons measured with fMRI. V. Troiani (1), J.E. Peelle (2), and M. Grossman (3). (1) University of Pennsylvania, Philadelphia, US. (2) MRC Cognition and Brain Sciences Unit, Cambridge, UK. (3) University of Pennsylvania, Philadelphia, US.

Quantity processing is known to rely on regions of the intraparietal sulcus (IPS), whether the task involves comparing numerical stimuli or abstract dot arrays. However, the role of the IPS in a conceptual size judgment tasks has not been fully elucidated. Are the same regions that are critical in evaluating visuo-spatial and magnitude differences involved in assessing the relationships of semantically similar object concepts? A recent study demonstrated significantly longer reaction times when comparing the sizes of written words depicting objects (i.e. bikini vs. coat) following transcranial magnetic stimulation (TMS) to parietal cortex (Cappelletti, Muggleton, and Walsh, 2009). The present study uses BOLD fMRI to more deeply explore the underlying neural processing of numerical (64 vs. 57) and semantic (twig vs. branch) size comparisons. Healthy young adults completed a task in which they chose the larger of two visually presented stimuli from one of two categories- Arabic numerals or semantically related objects. Stimuli pairs were presented randomly in an event-related design, with correct answers appearing in equal proportions on the left or right of the screen. Our results demonstrate that parietal cortex is not significantly activated during size assessments of objects. These results add functional evidence to the current debate of the putative role of the IPS, suggesting that parietal cortex is not critical for comparisons of objects along a size dimension. This suggests that more traditional temporal regions important for conceptual information may encode size as one feature of an object concept. Furthermore, this evaluation may not require parietal regions typically involved in size judgments. The role of parietal cortex in evaluating the size of semantically related concepts still demands further study. In order to be critically

tested, the behavioral profiles of patients with selective object comprehension and numerical processing deficits should be evaluated. The findings of the present study provide the first direct evaluation of cortical regions involved in semantic size processing using functional neuroimaging. Reference: Cappelletti, M., Muggleton, N., and Walsh, V. (2009). Quantity without numbers and numbers without quantity in parietal cortex.

33. The role of domain-general systems in language comprehension: Evidence from dual-task interference and semantic ambiguity. J.M. Rodd (1) I.S. Johnsrude (2) M.H. Davis (3). (1) University College London, UK (2) Queen's University, Kingston, Canada (3) MRC Cognition and Brain Sciences Unit, Cambridge, UK.

To fully understand a sentence, listeners must select the appropriate syntactic and semantic properties for each constituent word on the basis of its surrounding context. For example, in the phrase "the bark of the dog", the syntactic properties of the word "the" indicate that "bark" is being used as a noun and not as a verb, while the meaning of the word "dog" suggests that "bark" is referring to an animal noise and not to the outer covering of a tree. In some cases the critical disambiguating information is already available when the listener encounters the ambiguous word, while in other cases the disambiguating words may only occur later in the sentence and may result in a "garden-path" situation where the listener is required to reinterpret a sentence that was initially misparsed. A number of fMRI studies of such ambiguities [e.g., Rodd, Davis & Johnsrude (2005) *Cerebral Cortex* 15:1261-1269] have identified the posterior left inferior frontal gyrus (pLIFG) as a key brain region associated with ambiguity resolution. This region is not uniquely associated with sentence comprehension and it is also activated by a wide range of different tasks involving single words or pictures in which participants are required to select task relevant information [e.g., Thompson-Schill et al. (1997) *PNAS* 94:14792-7]. In the light of this apparent neural overlap, some authors have suggested that the neural mechanisms that are recruited to resolve sentential ambiguities may be domain-general control mechanisms that are also recruited by other non-sentential tasks [e.g., January et al. (in press) *Journal of Cognitive Neuroscience*]. Despite the intuitive appeal of this view, it is important to rule out the possibility that these functions are supported by adjacent but separable systems within the pLIFG. It is also important to note that this conclusion is in strong contrast to many cognitive models, which assume that sentential ambiguity resolution involves highly specialized linguistic processors. The two experiments reported here provide converging evidence that the cognitive processors used to resolve semantic ambiguities are also involved in non-sentential tasks. We use a dual-task method to measure the behavioural consequences of different types of semantic ambiguities for listeners' ability to perform a concurrent non-sentential task. While listening to a variety of types of sentences that contain semantic ambiguities, participants are simultaneously presented with a visually-presented letter. Participants must then decide as quickly as possible whether the letter is in upper or lower case. The results suggest that there is a reduction in performance on the case judgement task whenever listeners are simultaneously engaged in reinterpreting a sentence that they initially misparsed. This suggests that there is overlap between the cognitive system that is involved in semantic reinterpretation and the response-selection aspect of the case-judgment task. This supports the wider view that higher-level aspects of sentence comprehension, such as reinterpretation, relies on cognitive and neural systems that are not entirely specialised for sentence comprehension, but are also recruited for non-sentential tasks in which participants must select an appropriate response from a set of alternatives.

34. Context-dependent Encoding of Speech in the Human Auditory Brainstem, B. Chandrasekaran (1), J. Hornickel (1), E. Skoe (1), T. Nicol (1), and N. Kraus. (1) Auditory Neuroscience Lab, Northwestern University, Evanston, US.

According to the anchor-deficit hypothesis (Ahissar, 2007), children with poor reading skills demonstrate impairment in the ability to extract statistical regularities from the incoming stimulus stream, that may be an underlying cause for noise-exclusion deficits. The aim of the current study was to compare context-dependent brainstem encoding in children with developmental dyslexia (n=15) and a typically-reading control group (n=15), in order to determine the extent to which children with poor reading ability and noise-exclusion deficits are able to modulate or sharpen lower-level neural representation based on prior experience. We examined context-dependent brainstem encoding of speech in 30 school-aged children by measuring auditory brainstem responses to a speech syllable (/da/) presented in a repetitive (100% probability) or variable context (12.5% probability). Our results demonstrate that the human auditory brainstem responses are sensitive to stimulus context. Whereas typically developing children showed enhanced brainstem representation of speech in the repetitive context relative to the variable, dyslexic children did not differ on the two conditions. From a functional perspective, the extent of context-dependent encoding in the auditory brainstem positively correlates with behavioral indices of speech perception in noise. Our findings suggest that the inability to modify auditory representations based on prior experience may contribute to a noise exclusion deficit in developmental dyslexia.

Acquisition and Learning

35. Speech sound feature encoding and discrimination in children with phonological delay. A. Cummings (1,2), R. Ceponiene (2), J. Townsend (2). (1) University of North Dakota, Grand Forks, ND (2) University of California, San Diego, San Diego, US.

Children with phonological delay (PD) have difficulty producing, using, and integrating sounds of their target language system (Gierut, 1998). Phonological delays may potentially be caused by impaired speech sound perception abilities, and vice versa. It has been proposed that speech perception problems arise, at least in some cases, from faulty representation of the speech

signal in the central auditory processing centers (Kraus, 2001). Indeed, Rvachew and Jamieson (1995) have suggested that children with PD have [perceptual] knowledge deficits at the level of phonemic detail. This research program examined children's brain responses reflecting sensory encoding (sensory event-related potentials, ERPs) and attention-independent discrimination (mismatch negativity, MMN) of syllables containing sounds they could and could not produce with the aim of increasing their speech intelligibility. Five children with PD, aged 3 to 7 years (4 male), were enrolled in a speech treatment program that focused on the accurate production of a single, word-initial phoneme ("r", "ch", or "th"). Every child with PD completed 19 one-hour treatment sessions over the course of 3 to 4 months. Prior to the beginning of treatment and at the completion of his/her treatment, each child with PD completed an individually designed ERP experiment. The individualized ERP paradigms specifically targeted each child's selected treatment sound (i.e., a sound initially produced inaccurately), as well as a sound that each child could produce correctly. Five age-matched, typically developing controls (TD; 5 male) completed identical ERP paradigms with a similar amount of time between sessions and no intervention. Syllables (consonant + /a/) were presented in blocks, with 5 to 8 blocks presented to each participant per session. Within a block, four stimuli were presented using an oddball paradigm in which three infrequent, "deviant" stimuli (probability = 7% for each) were presented among frequent, "standard" stimuli (probability = 79%). One of the three deviant syllables contained each child's treatment sound, while the standard syllable contained his/her correctly produced sound. Stimuli were presented in a pseudorandom sequence and the onset-to-onset interstimulus interval varied randomly between 600 and 800 ms. ERPs were recorded via a 64-channel ActiveTwo data acquisition system (aligned according to the International 10-20 system), referenced to both mastoids. The amplitude of the auditory sensory P2 potential to the treatment sound was enhanced in the children with PD post-treatment as compared with pre-treatment. Moreover, in contrast to the TD children who showed a robust discriminatory brain response (the MMN), children with PD revealed no clear MMN response prior to treatment, suggesting that they had difficulty making subtle distinctions involving their treatment sound. Post-treatment, these children showed a large positivity, instead of a negativity (i.e., the MMN), in response to the deviant treated syllable. This treatment positivity was interpreted as a less efficient discriminatory response, generated in deeper cortical layers, possibly a pre-cursor of the typical discriminative response, the MMN. These findings suggest that children with PD may have abnormal perceptual processing of sounds that they cannot produce correctly.

36. The effects of tone language experience on pitch processing in the brainstem. *G. Bidelman (1), A. Krishnan (1), J. Gandour (1).* (1) Department of Speech Language Hearing Sciences, Purdue University, West Lafayette, US.

Neural encoding of pitch in the auditory brainstem is known to be shaped by long-term experience with language implying that early subcortical sensory processing is subject to experience-dependent neural plasticity. The aim of the present study was to determine to what extent this experience-dependent effect is specific to a particular language. Brainstem frequency following responses (FFRs) were recorded in native speakers of Mandarin Chinese, native speakers of Thai, and native speakers of American English in response to monosyllabic words containing one of three lexical Tones found in Mandarin (yī 'clothing' [T1]; yì 'aunt' [T2]; yì 'easy' [T4]) or Thai (yīM 'derogatory title' [TM]; yīR 'nasal sound' [TR]; yīF 'candy' [TF]), respectively. Pitch-tracking accuracy of the whole-contour (a measure reflecting the ability of the brainstem to faithfully follow pitch changes in the stimulus) and sectional pitch strength (a measure of the time-varying robustness in pitch encoding) were computed from the FFRs using autocorrelation algorithms. Analysis of variance of brainstem responses to Mandarin and Thai tones revealed that regardless of language identity, pitch-tracking accuracy of whole tones was higher in the two tone language groups (Chinese, Thai) compared to the non-tone language group (English). Similarly, pitch strength was generally more robust across the duration of the responses for the tone language groups relative to the English group. Discriminant analysis of tonal sections, as defined by variation in direction and degree of pitch acceleration, showed that moderate rising pitch was the most important variable for classifying English, Chinese, and Thai participants into their respective groups. We conclude that long-term experience sharpens the tuning characteristics of neurons along the subcortical pitch axis, thereby enhancing sensitivity to linguistically-relevant variations in pitch. Furthermore, language-dependent enhancement of pitch representation transfers to other languages with similar phonological systems. From a neurobiological perspective, these findings suggest that neural mechanisms local to the brainstem are tuned for processing perceptually salient pitch dimensions depending on the requirements of the melodic patterns found in an individual's native language.

37. Assessing Infants' Cortical Response to Speech Using Near-Infrared Spectroscopy. *H. Bortfeld (1), E. Fava (2), and D. Boas (3).* (1) University of Connecticut, Storrs, CT. (2) Texas A&M University, College Station, TX. (3) Martinos Imaging Center, Charlestown, US.

The present research employs near-infrared spectroscopy (NIRS) as a method for assessing region-specific neural processing in infants in response to language. NIRS is an optical imaging technology that uses relative changes in total hemoglobin concentration and oxygenation as an indicator of neural activation. In previous work using NIRS (Bortfeld et al., 2007), we observed robust and reliable patterns of neural activation in the left temporal and primary occipital regions of young infants' brains during their exposure to sensory-specific material, as indicated by NIRS-based measures of cerebral blood flow and volume change. Given this initial methodological step, we now use NIRS to interrogate the bilateral temporal cortices, regions of the infant brain that are specific to processing various forms of auditory stimuli. Here we focus our attention on older infants who were actively engaged in multimodal perceptual processing. The reason for this was twofold. First, older infants present a challenge to existing technologies (e.g., fMRI) that might require swaddling to limit the movement typical of this active stage of

development; our study examines a potential way of circumnavigating this limitation. Second, behavioral research indicates that a variety of language-specific processing biases emerge in the second half of the first year (Bortfeld, Morgan, Golinkoff, & Rathbun, 2005; Singh, Nestor, & Bortfeld, 2008; see Werker & Curtin, 2005, for a review); this population represents an age of emerging language sensitivity. Older infants (aged 6-9 months) were tested in two conditions: during exposure to speech coupled with visual stimuli (audiovisual condition) and during exposure to visual stimuli alone (visual only condition). Two hypotheses were tested: First, that significant change in neural activation—as measured by an increase in oxygenated hemoglobin (HbO₂)—would be observed in the left superior temporal region in response to the audiovisual condition relative to the visual condition, and second, that relatively little change in neural activation would be observed in the right superior temporal region in response to either condition. We reasoned that only the audiovisual condition included auditory features that would elicit spectral-specific processing in the temporal regions, and that the language-specific nature of those features would lead to greater activation of the left relative to the right temporal area. Furthermore, and in contrast to other recent findings (e.g., Homae et al., 2007), we did not expect to see significant recruitment of the right relative to the left temporal region. This was because, where Homae et al. (2007) highlighted the prosodic aspects of linguistic stimuli by contrasting artificially induced acoustic characteristics, the auditory component of our audiovisual stimuli was not contrasted with any other form of acoustic stimuli. Results revealed a dissociation of sensory-specific processing in two cortical regions, the left and right superior temporal lobes. These findings are consistent with those obtained using other neurophysiological methods, pointing to the utility of NIRS as a means of establishing neural correlates of language development in older (and more active) infants. We are now comparing older infants' neural responses to different forms of auditory stimuli (e.g., speech vs. music).

38. The encoding of identity and sequential position in newborns: an optical imaging study. *J. Gervain (1), I. Berent (2), J. Werker (3). (1) University of British Columbia, Vancouver, Canada (2) Northeastern University, Boston, US (3) University of British Columbia, Vancouver, Canada.*

Several languages manifest constraints that favor the right edge of phonological domains. Semitic languages constrain the occurrence of repetitions in their consonantal roots to the final position (smm 'drug'), and disallow repetitions in the initial position (*ssm; Berent et al. 2004). Suffixing is much more frequent in the world's languages than prefixing and lexical stress is more commonly assigned to the ultimate or penultimate syllables of words than to the initial ones (Dryer 1992, Goedemans & van der Hulst 2008). What are the origins of such constraints on phonological and morphological structure? Are the constraints favoring sequence-final positions present in the initial state and later regress in speakers whose languages do not manifest them, or are such constraints initially absent and they emerge only later as a result of language experience. Previous brain imaging research (Gervain et al. 2008) has found that newborns are able to detect and learn structures containing immediate repetitions in final positions (ABB: "mubaba"). In the current study, we conducted three functional near-infrared spectroscopy (NIRS) experiments with newborns (0-4 days) to investigate their ability to detect sequence-initial repetitions (AAB: "babamu") and compare the processing of initial and final repetitions. In Exp 1 (n=24), we tested whether newborns process repetition-initial patterns (AAB: "babamu") differently from random controls (ABC: "mubage"). Similarly to the ABB vs. ABC comparison (Gervain et al. 2008), newborns in this study exhibited a significantly greater brain response to the AAB sequences as compared to the ABC ones, in particular in the auditory areas of the left hemisphere (Pattern × Hemisphere: p=0.050; Area of Interest: p=0.020; Fig. 1). In Exp 2 (n=24), we directly compared AAB and ABB sequences, and found remarkably similar responses to the two patterns, especially in the left and right auditory areas (Fig. 2; Pattern × Hemisphere: p=0.818, ns.). These results suggest similar processing mechanisms are involved in the encoding of the two patterns. At birth, the two are equally easy to encode. To investigate another possible interpretation, namely that newborns only detect the repetitions, but not their position, we are currently running Exp 3 to test whether newborns are able to discriminate AAB and ABB patterns in an alternating/non-alternating paradigm. If Exp 3 reveals that newborns can discriminate the patterns, but still show no preference, as Exp 2 suggests, then constraints favoring the right edge might develop as a result of language experience.

39. One for all: Unitary brain network serves both lexical-semantic and syntactic learning. *J. L. Mueller (1) A. Nakamura (2) S.-A. Rüschemeyer (3) K. Ono (2) M. Sugiura (4) N. Sadato (5) A.D. Friederic (1). (1) Max Planck Institute for Human Cognitive and Brain Sciences Leipzig (2) National Center for Geriatrics and Gerontology, Obu (3) Donders Institute for Brain, Cognition and Behaviour, Nijmegen (4) Institute of Development, Aging and Cancer (IDAC), Tohoku University (5) National Institute for Physiological Sciences, Okazaki.*

The present study used blood-oxygen-level-dependent (BOLD) fMRI to investigate language learning processes in a near-natural setting. The use of a single visual-context-learning task allowed for the direct comparison of learning related neural activation during listening to novel syntactic and lexical-semantic information. Japanese native speakers were trained in a miniature version of German prior to fMRI scanning. During scanning they were presented with familiar sentences, sentences containing a novel rule and sentences containing a novel word while visual context provided the necessary information for learning. Both syntactic and lexical-semantic learning were associated with a decrease of activation over time in a largely overlapping fronto-parietal network including basal ganglia structures. While the activation changes in the syntactic condition appeared as sudden changes after only one single learning block the lexical-semantic condition led to more gradual decreases of activation. This result is in concord with conceptions of rule learning as an all-or-nothing process and lexical-semantic

learning as a more gradual associative mechanism. Thus, the main difference between the neural underpinnings of syntactic and lexical-semantic learning in a natural language learning task seems to lie in the temporal dynamics of activation changes and not in their localization.

40. The time-course of form and meaning consolidation in novel word acquisition. G. Gaskell (1), S. Lindsay (1), J. Tamminen (1), Y. Chen (1)(2), R. Li (1), J. Wolfson (1), A. Gouws (1), M. Simpson (1), P. Gagnepain (2), M. Davis (2). (1) University of York, York, UK (2) MRC Cognition and Brain Sciences Unit, Cambridge, UK

Behavioral and neuroimaging data suggest that acquiring novel spoken words without meanings involves two components: immediate acquisition of phonological representations, followed by sleep-associated integration with lexical neighbors (1, 2). The current study used fMRI to examine the acquisition of novel written words with meanings. Adult participants learned to associate two sets of visually presented novel words and meanings on consecutive days. On day 2, BOLD responses to both sets of novel words, plus untrained pseudowords and existing words, were measured during a one-back meaning comparison task. Data from behavioral tests showed that participants could access meanings for both trained novel words sets reasonably well. Using untrained pseudowords as a baseline, retrieval of the meanings of both novel word sets engaged a broad network including bilateral inferior temporal regions, and left inferior and middle frontal gyrus. However, compared with the pre-existing words, novel words exhibited substantially weaker responses in left occipitotemporal regions. Following (1) we conducted two ROI analyses. We expected immediate learning effects in the left hippocampus (3, 4), and this was confirmed. The BOLD response to completely novel pseudowords was significantly higher than the response to novel words presented repeatedly that day. This can be interpreted as either a habituation effect to familiar stimuli or a novelty effect to unfamiliar ones. A second analysis focused on regions that showed stronger responses to pseudowords than words. Of these, one region of left lateral occipitotemporal cortex also showed a significant Bonferroni-corrected difference between the novel words conditions; items learned on the day of testing patterned with pseudowords whereas items learned on the preceding day showed a more word-like response (see Figure 1). The data provide support for a dual-systems model of visual word recognition (cf. 5), whereby the medial temporal lobe performs a binding role, supporting initial learning and processing of novel words. Over time, and perhaps sleep, the novel information is then integrated in the neocortex, allowing specialized cortical areas to take over the word recognition process. The fact that both behavioral and fMRI data imply that semantic access is possible for both novel types suggests that both recognition routes can link to semantic areas. References. 1. Davis, M.H., Di Betta, A.M., Macdonald, M.J.E., & Gaskell, M.G. (2009). Learning and consolidation of novel spoken words. *Journal of Cognitive Neuroscience*, 21, 803–820. 2. Dumay, N., & Gaskell, M.G. (2007). Sleep-associated changes in the mental representation of spoken words. *Psychological Science*, 18, 35-39. 3. Breitenstein, C., Jansen, A., Deppe, M., Foerster, A.F., Sommer, J., Wolbers, T., et al. (2005). Hippocampus activity differentiates good from poor learners of a novel lexicon. *Neuroimage*, 25, 958-968. 4. McClelland, J.L., McNaughton, B.L., & O'Reilly, R.C. (1995). Why there are complementary learning-systems in the hippocampus and neocortex - insights from the successes and failures of connectionist models of learning and memory. *Psychological Review*, 102, 419-457. 5. Davis, M.H., & Gaskell, M.G. (in press). A complementary systems account of word learning: neural and behavioural evidence. *Philosophical Transactions of the Royal Society*.

41. The role of procedural memory in language learning: cognitive and neural evidence. M. Ettlinger (1), A. Bradlow (2,3), P. Wong (1,3). (1) The Roxelyn and Richard Pepper Department of Communication Sciences and Disorders, and Northwestern University Interdepartmental Neuroscience Program, Northwestern University, Evanston, IL (2) Department of Linguistics, Northwestern University, Evanston, IL (3) Hugh Knowles Center for Clinical and Basic Science in Hearing and Its Disorders, Northwestern University, Evanston, US.

Introduction: While there has been recent interest in the neural mechanisms of second language learning (e.g., Wong et al., 2007), how such learning is tied to broader neurocognitive processes remained to be explored. Here we present converging evidence from both behavioral and neurophysiological studies implicating the procedural memory system and the basal ganglia in the acquisition of complex morphological interactions. The behavioral evidence shows that a significant amount of the variance in success at learning the complex words of an artificial language can be accounted for by participants' success as a standardized procedural learning task, controlling for both working memory and success at learning simple words. The neurophysiological study shows increased activation of the basal ganglia, an area associated with procedural learning (Squire & Knowlton, 2000), during acquisition of complex words relative to simple ones. Furthermore, degree of activation of the basal ganglia correlated with individual learning success. Methods: Native English-speaking healthy adult participants were taught an artificial language, which consisted of 12 nouns and two affixes and a grammar of how they can be combined. Crucially, half of the nouns underwent a number of complex interacting grammatical processes when the affixes were added while affixation for the other half of the nouns involved simple concatenation. Training consisted of participants seeing a picture while hearing the corresponding word for that picture in the language. Afterwards, participants were tested as to whether they learned the language using a forced-choice test. For the behavioral study, participants subsequently took a battery of standardized cognitive tests (Woodcock Johnson, Tower of London) while for the neurophysiological study, cerebral hemodynamic responses were measured using fMRI during training. Results: Behavioral results indicate variable learning by participants in both studies. In the behavioral study, a positive correlation between learning success and procedural learning ability (measured by standardized cognitive tests) were found. In the fMRI study, when comparing the neural activation during the acquisition of words involving the interaction of several grammatical processes, to simple, grammar-less words, greater activation was found in basal ganglia

structures. There was also a strong correlation between activation in those areas and learning success. Conclusion: These two studies provide converging evidence for a crucial role for procedural learning in the acquisition of complex interactions in language. This lends support to the Declarative/Procedural hypothesis (D/P; Ullman, 2001), which associates certain linguistic functions with different types of memory. In DP, words (lexicon) are associated with declarative memory, while grammar, operating over lexical items, combining and modifying them, is associated with procedural memory. More broadly, this supports the idea that these basic linguistic functions are supported by basic cognitive processes and different kinds of memory. Selected references Squire, & Knowlton (2000). The medial temporal lobe, the hippocampus, and the memory systems of the brain. In Gazzaniga (Ed.), *The new cognitive neurosciences*. Ullman (2001) The declarative/procedural model of lexicon and grammar. *J. Psycholinguistic Research*, 30. Wong, Perrachione & Parrish (2007). Neural Characteristics of Successful and Less Successful Speech and Word Learning in Adults. *Human Brain Mapping*, 28, 995-1006.

42. Predicting later language outcome in toddlers with Autism; correlating behavioral measures with Event related brain potentials to word stimuli.

S. Coffey-Corina (1) D. Padden (2) P. Kuhl (3). (1) University of California, Davis, Center for Mind and Brain, Davis, CA (2) University of Washington, Institute for Learning and Brain Science, Seattle WA. (3) University of Washington, Institute for Learning and Brain Science, Seattle WA.

Toddlers (19- 30 months) newly diagnosed with Autism Spectrum Disorder (ASD) participated in a research study that involved both electrophysiological and behavioral measures. Event related potentials (ERPs) were recorded during auditory presentation of known (based on parental report), unknown, and backwards words. Behavioral measures of language/cognitive function and severity of autism symptoms were also collected at the time of ERP testing and again one and two years later. Dividing children with autism into high and low functioning groups, by taking a median split using ADOS scores (a measure of severity of autism symptoms) produced different patterns of ERPs to both known and unknown words. Backwards words were processed in a similar manner by both groups. Higher functioning toddlers with autism (children with lower ADOS scores) had greater negativity to known words and more focused brain response to differences between known and unknown words, these differences were larger in the left hemisphere, similar to typically developing age matched controls. Lower functioning toddlers with autism showed a more diffuse pattern of differences between known and unknown words, across many sites and larger in the right hemisphere. Specific differences between groups of children and word types started at 100-200 msec after word onset (positivity) and negativities between 300 and 700 msec after word onset. In addition, significant correlations were obtained between specific brain wave measurements for both known and unknown words and the various behavioral measures -- patterns of ERPs could effectively predict behavioral scores.

43. Noninvasive stimulation over the motor cortex influences learning of a novel action word lexicon.

G. Liuzzi (1), V. Ridder (1), M. Zimmerman (1), C. Dobel (2), S. Enriquez-Geppert (2), C. Gerloff (1), P. Zwitserlood (3), F. Hummel (1). (1) Brain Imaging and Neurostimulation Lab (BINS), Department of Neurology, University Medical Center Hamburg-Eppendorf, Germany (2) Institute for Biomagnetism and Biosignalanalysis, University of Münster, Germany (3) Department of Psychology, University of Münster, Münster, Germany.

The embodied cognition theory suggests that motor cortical areas are automatically accessed and necessarily involved in the understanding of action words. According to Hebb's associative model it has been proposed that during language acquisition the frequent co-occurrence of action words and action performance finally leads to hardwired connections of perisylvian areas, which process word form, with the motor cortex, where action-related semantic concepts are grounded. However, it has not been investigated yet whether interference with motor cortical processing affects the acquisition of action words. We thus probed the functional relevance of the motor cortex for learning a novel action word vocabulary with transcranial direct current stimulation (tDCS) in 30 young, healthy subjects. In a placebo-controlled double-blind and randomized parallel design, each subject received daily either anodal, cathodal (VERUM groups; 1mA, 20 min) or sham (PLACEBO group) tDCS over the left primary motor cortex over 4 consecutive days (days 1-4). After application of tDCS, subjects were trained in a novel vocabulary of 76 concrete action words by means of an associative learning paradigm (Fig. 1). Verum compared to sham tDCS significantly impaired learning speed and translation of novel action words into the native language (Fig. 2). The results lend first evidence that the left motor cortex is involved in the acquisition of a novel action word vocabulary.

44. Common themes of brain mechanisms for song in birds and spoken language in humans.

Jarvis ED (1). (1) Duke University Medical Center and Howard Hughes Medical Institute, US.

Vocal learning is a critical behavioral substrate for song in song learning birds and spoken language in humans. Of the vocal learning species whose brains have been studied to date (songbirds, parrots, hummingbirds, and humans), all have been found to have a forebrain to brainstem system that controls vocalizations, whereas those species that produce only innate vocalizations (chickens, pigeons, chimpanzees, monkeys, and cats) have only the brainstem vocal system. Using behavioral, molecular, electrophysiological, and anatomical approaches we found that the song learning systems of the three distantly related vocal learning birds are each embedded within a motor system involved limb and body movements. We found that this motor system is also present in vocal non-learning birds, but without a song system embedded within it. The song learning and adjacent motor systems share many properties in common, including motor-driven gene expression cascades, and similar connectivity and functions consisting of an anterior forebrain pathway that in songbirds is necessary for song learning and a posterior motor pathway that is necessary for song production. These pathways appear to have parallels with those for spoken

language in humans. A computational analysis of genomic sequences in vocal learning mammals (humans, bats, dolphins, and elephants) versus vocal non-learning mammals (chimpanzees, macaques, dogs, and cows) suggest that mutations in axon guidance molecules could be responsible for the formation of the new vocal learning brain systems. To explain these findings, I propose a motor theory for the origin of vocal learning and other complex motor behavioral traits. For this theory, I propose that much like gene evolution, an ancient brain system used to control movement and motor learning, such as learning how to walk, fly, or gesture, duplicated and then diverged axon guidance mutations to directly connect to the brainstem motor neurons that normally control innate vocalizations, but now control song and spoken language. The pre-existing system, I argue, is a fundamental design of the vertebrate brain, consisting of the two motor sub-pathways (anterior and posterior), which during embryonic development form parallel systems to control different muscle groups that are innervated by sensory systems for feedback control of different motor behaviors. In this manner, the evolution of brain pathways for vocal learning may have evolved independently of a common ancestor in distantly related birds and in humans, but dependent on a pre-existing genes and a pre-existing motor learning pathway with deep evolutionary roots.

45. Oscillatory correlates of grammatical plasticity. D. J. Davidson (1), P. Indefrey (2,3,4). (1) Max Planck Institute for Human Cognitive and Brain Sciences, Leipzig, Germany (2) Max Planck Institute for Psycholinguistics, Nijmegen, The Netherlands (3) Donders Institute for Brain, Cognition and Behaviour, Nijmegen, The Netherlands (4) Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany.

Electrophysiological research on second language (L2) learning most often relies on the averaged evoked response (ERP), but there is now substantial evidence from L1 research that oscillatory spectral power can provide a complementary measure of cortical activity. In particular, greater amplitude theta band power has been observed in response to violations of L1 grammatical constraints. The present work examined whether changes in oscillatory power can be observed during language learning. Native Dutch speakers ($n=20$) classified German prepositional phrases presented serially as text (0.5 s ISI) over several learning sessions while EEG was recorded. The phrases included gender and declension violations and controls. A measure of evoked spectral power indicated greater amplitude theta band (3-8 Hz) activity to grammatical violations one week after training began (see Figure 1, which shows time-frequency spectra for the post-training violation, control, and the contrast of the two, with respect to the onset of the critical word). There was also greater amplitude theta band activity in response to feedback for incorrect classifications during learning, in agreement with previous demonstrations of theta band reactivity to feedback indicating incorrect response choices. A source reconstruction indicated bilateral inferior frontal and superior temporal cortex activity for the grammatical violation effect, and in addition, anterior cingulate activity for the feedback effect. These results suggest that event-related oscillatory activity in the theta band is related to the learning of morpho-syntactic discrimination.

46. Differences in parental language predict Broca's structure in five-year-olds. G. Cardillo Lebedeva (1,2), S. Bhagat (1,2), R. Raizada (1), P.K. Kuhl (1,2). (1) Institute for Learning & Brain Sciences, University of Washington, Seattle, U.S. (2) Dept. of Speech & Hearing Sciences, University of Washington, Seattle, U.S.

Background: While it is clear that differences in quality and quantity of language input that occur across socioeconomic statuses (SES) influence language development (e.g., Hart & Risley, 1995), less is known about how these factors directly affect neural development in young children. A recent fMRI study on 5-year-old children reported that SES was positively correlated to hemispheric specialization in the inferior frontal gyrus (IFG; Broca's area) during a rhyme detection task, after controlling for multiple measures of language and IQ (Raizada, et al., 2008). To investigate the possibility that linguistic input mediates this relationship, the present study used the same sample to analyze syntactic complexity of child-directed maternal language in play and storytelling contexts. Based on previous literature, we predicted that maternal syntactic complexity would vary across both SES (Huttenlocher, et al., 2002) and context (Hoff, 2003). In addition, the relationships between and structural/functional measures in language regions of the brain were explored, where hemispheric specialization was predicted to vary with input complexity. Methods and Results: The proportion of mothers' multiclausal utterances was measured from both a naturalistic story generation task and play interaction ($N=17$). The Hollingshead Index SES range was from 32-66 ($M=53$, $SD=11$). Child language was measured by the receptive-expressive composite score on the CELF-P, a normed test. Based on a median split of SES, mothers' syntactic complexity was higher during storytelling than during play for both groups ($p=.001$, $\eta^2=.53$), whereas mothers with higher SES tended to use higher complexity during play than mothers with lower SES ($p=.05$, $\eta^2=.23$), in accordance with the hypotheses. Moreover, of the children who completed fMRI scans ($N=14$), the proportion of complex utterances produced by all mothers, independent of context, was positively correlated to left, but not right, IFG gray matter volume, after both SES and child language were partialled out ($r=.59$, $p<.05$). Further analyses suggested that neither the behavioral nor the imaging effects were driven by the use of mental state verbs such as think and know, which are typically constructed within embedded clauses. The behavioral findings support the idea that differences in language input complexity are minimized across SES in more structured contexts such as storytelling as compared to less structured contexts. The brain imaging results suggest that more complex language stimulation in the home environment is related to the development of neural structures specialized for language, particularly syntactic processing. While directionality cannot be directly addressed, the 35% unique variance in left IFG area that was explained by syntactic complexity provides evidence that the richness of the language environment may influence the brains of children, furthering our understanding of specific brain-behavior links, and of parental language assessment. Hoff, E. (2003). The specificity of environmental influence: socioeconomic status affects early

vocabulary development via maternal speech. *Child Development*, 74(5), 1368-1378. Huttenlocher, J., Vasilyeva, M., Cymerman, E., & Levine, S. (2002). Language input and child syntax. *Cognitive Psychology*, 45, 337-374. Raizada, R., Richards, T., Meltzoff, A., Kuhl, P. (2008). Socioeconomic status predicts hemispheric specialization of the left inferior frontal gyrus in young children. *NeuroImage*, 40(3), 1392-1401.

Multilingualism

47. Impaired language switching but intact language selection in bilinguals with aphasia. A. Miller Amberber (1) L. Nickels (1) M. Coltheart (1) S. Crain (1) R. Thornton (1). (1) Macquarie Centre for Cognitive Science, Macquarie University, Sydney, Australia.

Language-switching (code-switching) is the fluent alternation of languages within a single utterance or sentence spoken by proficient bilinguals. Code-switching is constrained both by discourse principles e.g. selective use of language A, B or both according to the speaker, context, topic; and by grammatical principles, such that language-switching occurs only between specific grammatical constituents in a sentence. For example, there is strong cross-linguistic evidence of code-switching between a noun phrase subject and grammatically-inflected verb but not between a subject pronoun and inflected verb e.g. "la femme eats the apple" but not "*elle eats the apple". Proficient adult early bilinguals maintain language selection/control in bilingual and monolingual contexts, and grammatical and semantic coherence in code-switched and single-language sentences. Aphasic (previously proficient) bilinguals may have impaired language selection e.g. code-switch with monolinguals, but evidence of grammatical impairment of code-switching is inconclusive. In this study we investigated whether early bilinguals with aphasia demonstrate grammatically-impaired code-switching and whether the grammatical and the discourse components of code-switching are both impaired. Furthermore, our study included aphasic participants with left subcortical only versus cortical lesions. Using a single case-control design, we examined the code-switching of 5 adult early bilinguals with aphasia and 5 bilingual controls, individually matched for languages, bilingual history and demographic factors. The language pairs spoken were Rarotongan Cook Island Maori-English, Maltese -English, French-English. We compared the performance of the aphasic bilinguals and controls for the number of verbs produced in the same language as the sentential subject in dual language and single language sentences with a pronoun versus a noun phrase subject. Two tasks were used (a) Spoken production (b) Lexical selection. Specifically we sought to answer: do aphasic bilinguals produce and select verbs in the same language as the pronoun subject, like controls? The results showed that the aphasic bilinguals produced and selected verbs that did not match the language of the pronoun subject on dual language sentences, unlike controls. Aphasic bilinguals were able to produce these verbs in the same language as the sentential subject on single language sentences, like controls. Both aphasic participants and controls produced and selected verbs that did not match the language of the noun phrase subject. Some aphasic bilinguals performed better on lexical selection than spoken production in dual language sentences. Both the aphasic bilinguals and controls consistently selected and maintained use of the target language(s) in monolingual and bilingual contexts, during conversation, recounting narratives and reading aloud experimental stimuli. The same pattern of grammatically impaired code-switching and intact language selection was seen across the different language pairs. Further more, the same pattern of results was seen for aphasic participants with left subcortical versus cortical lesions. Overall, these results provide further evidence of a dissociation between language-switching and language selection/control. Aphasic bilinguals can have an impaired ability to code-switch, to control language selection, or both, as well as impaired ability in each language. The results for these aphasic bilinguals are suggestive of impaired rapid alternation between languages rather than impaired inhibition of the non-target language.

48. Bilingual speech production as a sensorimotor skill. A. Simmonds (1), N. Dhanjal (2), R. Wise (3), and R. Leech (4). (1) MRC Clinical Sciences Centre, Imperial College, London, UK (2) Imperial College, London, UK (3) MRC Clinical Sciences Centre, Imperial College, London, UK (4) Imperial College, London, UK.

Speech production, whether native or non-native, is a complex sensorimotor process, relying on auditory and somatosensory feedback systems for self-monitoring and rapid adaptation. Bilingualism provides a good model for investigating these high-level feedback processes supporting speech production. Previous work has suggested speech involves the interplay between sensory feedback, which may be gated, and motor feedforward mechanisms. In this study, it was predicted that speaking a non-native language requires modifications to the speech motor-control system, during which the monitoring of feedback may be enhanced. In addition, it was predicted that these modifications relate to language proficiency. We used fMRI to investigate how feedback and feedforward mechanisms relate to speaking native (L1) and non-native (L2) languages, and how they are modulated by language proficiency. We scanned highly proficient speakers of English as a second language, who were all late unbalanced bilinguals, having acquired L2 after L1, but they had all had considerable exposure to L2 as they were living in England. Proficiency in English was assessed prior to scanning, using standardised language tests. In the fMRI scanning session, participants produced overt propositional speech in both their native language and English. In addition, functional localisers identified auditory, somatosensory and motor networks likely to be involved in feedforward and feedback control of the articulators. The results suggest a different pattern of both feedback and feedforward systems for L1 and L2. Contrasting L2 speech production with that in L1 showed increased activity in both motor and somatosensory areas and, most prominently, in midline cerebellum. Previous studies of bilingualism have concentrated on differential demands on linguistic processes between

languages. The results presented here demonstrate that the motor-sensory demands on producing a language learned after the period of 'innate' language acquisition of infancy have an impact; that is, the consequences of speaking with an accent.

49. The whole is more than the sum of its parts: Vowel discrimination in simultaneous bilinguals as reflected by the mismatch negativity. *M. Molnar (1), S. Baum (1), L. Polka (1), L. Ménard (2), K. Steinhauer (1).* (1) McGill University, Montreal, Canada (2) Université du Québec à Montréal (UQAM), Montréal, Canada.

Mismatch negativity (MMN) responses are capable to reflect whether language users have developed long-term memory traces in response to phonemes and whether they are able to perceive small acoustic changes within speech sound categories. Subtle acoustic changes within a phonemic category are often irrelevant to monolingual perceivers, but can be crucial for bilingual perceivers if the acoustic change differentiates the phonemes of their two languages. In the present study, we investigated whether bilinguals, unlike the monolingual speakers, are sensitive to such acoustic changes. If so, this would shed light on specific way in which simultaneous bilinguals represent vowels from different languages. **Methods.** We recorded MMN components from monolingual speakers (English, n=13; French, n=11) and simultaneous English/French bilingual speakers (n=14) using an unattended auditory oddball paradigm contrasting four vowels: English [u], French [u], French [y], and an acoustically-distinct control [ɣ] (located between the English [u] and the French [y] in the acoustic vowel space). Our design consisted of four experimental blocks of trials. In each block, a different vowel appeared as the standard stimulus, and the respective other vowels served as deviants. This way, each vowel was presented both as a standard and as a deviant in contrast to all the other vowels. **Results.** In line with previous behavioral and EEG findings, monolinguals were more sensitive to the phonemic status of the vowels than to the acoustic properties differentiating the sounds. On the other hand, bilingual speakers revealed a more complex pattern of ERP results. They did not only show the same MMN patterns as the two monolingual groups (combined) but, unlike any of the monolingual groups, were able to discriminate between the English [u] and the non-phonemic control [ɣ]. This ability suggests that the neuronal representation of the perceptual vowel space in simultaneous bilingual speakers benefits from an additional phonemic boundary between these two vowels. **Conclusion:** To our knowledge, this is the first ERP study employing a balanced oddball design investigating a 4-vowel contrast in simultaneous bilingual adults. Our findings advance the field by providing initial support for a single-system view on this largely under-researched population. More specifically, this single system cannot be viewed as a pure combination of the two monolingual representations of the vowel space. In contrast, the novel MMN findings described above seem to imply a unique system of vowel representation in simultaneous bilinguals that accommodates phonemes of both languages at the same time.

50. When I see their faces, I can't keep away from their interference. *Y. Wang (1,2), P. K. Kuhl (1), P. S. Stock (1).* (1) Institute for Learning and Brain Sciences, University of Washington, Seattle, US. (2) National Key Laboratory of Cognitive Neuroscience and Learning, Beijing Normal University, Beijing, China.

It's well known that the cognitive and neural mechanisms of bilingual processing are affected by AOA and L2 proficiency level. However, there has been little research into the role of other factors, such as social information, in bilingual processing. In the present study, we used fMRI to assess brain activity in English-Chinese bilinguals during a written language task that required matching a picture with a corresponding name of the picture in either the L1 or L2 condition with different social cues (incongruent, congruent, and no social cue). The results showed that, for English-Chinese bilinguals, when they process the task in English (L1) with different social cues, no significant activation was noted across different contrasts. However, when they process the task in Chinese (L2), the English social cue (incongruent cue) induced increased activation in the left frontal areas relative to the Chinese social cue (congruent cue) and to the no social cue conditions; no additional activation was found for other contrasts. Our results suggest that, when bilingual speakers process their less dominant language, the incongruent social cue interferes with their processing, manifested by the involvement of the executive regions to handle interference from the incongruent social cue. **Keywords:** Bilingual control, Executive function, Interference, Social information **Acknowledgements** This work was supported by a National Science Foundation Science of Learning Center grant to the UW LIFE Center (SLC-0354453, PI, P. Kuhl)

51. ERP evidence of native language influence on the processing of late acquired second language. *J. E. Drury (1), N. Bourguignon (2), T. Lin (1), K. Steinhauer (1).* (1) McGill University, Montreal, Canada (2) Université de Montréal, Montreal, Canada.

We investigated the influence of native language (L1) grammar/parsing on the processing dynamics of a late acquired second language (L2) (i.e., "transfer effects"). Native French speaking late/adult-learners of English ("French-L1" group) were tested along with native controls ("English-L1") in a sentence reading/judgment study conducted in English. Our focus was on violation paradigms in three domains where English/French syntax differ: word order properties of adjectival [1a-d] and adverbial [not shown here] modification, and number marking in indefinite [2a/b] and bare [2c/d] noun phrases (note: "*" marks corresponding ungrammaticality in English/French). English French [1] a ...white vase... OK * b ...vase white... * OK c ...big vase... OK OK d ...vase big... * * [2] a ...built a bridge in... OK OK b ...built a bridges in... * * c ...built bridges in... OK * d ...built bridge in... * * These conditions allowed us to address the following kinds of empirical questions: (Q1) What happens when you encounter an ungrammatical sentence in your L2 which is grammatical in your L1? (Q2) What happens when you encounter a grammatical sentence in your L2 which is ungrammatical in your L1? For example, L1 and L2 (un)grammaticality may coincide, as with the [1c/d] and [2a/b] contrasts. Alternatively, L1 and L2

grammars could make contradictory (e.g., [1a/b]) or inconsistent (e.g., [2c/d]) demands on processing systems. Despite the growing body of work examining L2-acquisition/-processing in cognitive neuroscience (e.g., using fMRI, ERPs), there is presently next to no available evidence bearing on these kinds of potential (positive/negative) L1/L2-transfer effects. Methods. Participants in both the French-L1 (n=11) and English-L1 (n=13) groups sat in a shielded booth and silently read the critical sentences on a computer monitor. Sentence stimuli were presented R.S.V.P. (300 ms with a 200 ms ISI), and participants performed end-of-sentence acceptability judgments. EEG was recorded continuously from 19 electrodes and data were analyzed using EEProbe software. Results. The English-L1 group showed late P600-like positive deflections for both adjective violations (i.e., [1b/d] > [1a/c]), and for both of the number marking violations (i.e., [2b/d] > [2a/c]). In contrast, the French-L1 group demonstrated different effects for the adjective sub-conditions: an N400 followed by a small P600 for [1b] versus [1a], and just a (larger) P600 effect for [1d] relative to [1c]. The [2b] number marking clash with the singular indefinite determiner also differed from the English-L1 group, eliciting only an N400 effect relative to [2a], while the [2c/d] contrasts yielded no such effects at all. However, direct comparison of the wave-forms the [2c/d] contrast across the English-/French-L1 groups showed these two conditions for the French-speakers patterned with the violation condition of the English-speakers. Conclusion. These (and other) findings from the present study offer the first clear evidence of qualitatively distinct ERP effects across comparisons which differentially tap possible (positive/negative) L1-influences on L2-processing.

52. Grammatical gender processing in second language reveals Event-Potential correlates indicative of early stages of grammaticalisation. H. Carrasco (2), C. Frenck-Mestre (1,2). (1) Centre National de Recherche Scientifique (2) Université de Provence, France.

The present study explored the neurocognitive processes underlying grammatical gender agreement in French as a first (L1) and second language (L2). Event-Related brain potentials (ERP) studies in L1 have evidenced distinct syntactic and semantic aspects of comprehension (Osterhout & Nicol, 1999). Morpho-syntactic anomalies, including agreement violations, can provoke a P600 component while semantic anomalies elicit a N400 component. ERP studies in proficient adult L2 learners generally find a native-like P600 effect for grammatical gender violations (Frenck-Mestre, Foucart, Carrasco & Herschensohn, in press; Sabourin & Stowe, 2008). However, other studies concerning low and high proficient bilinguals have shown that neural correlates of grammatical processing differ as a function of their level of proficiency. In early stages of acquisition learners are sensitive to grammatical anomalies, though electrophysiological responses differed from those observed in native speakers (Osterhout et al., 2006). Herein, electrophysiological responses were recorded in native French speakers (16) and low-proficiency English-French bilinguals (16) when processing gender agreement in sentential context. Grammatical and ungrammatical sentences were presented in which grammaticality was manipulated by gender agreement between the noun and post-posed adjective (e.g. *la musique française vs. français**). Nouns were either masculine or feminine. French native speakers and L2 learners showed neural sensitivity to gender concord errors; however ERP patterns differed across participant groups and across individuals in the group of L2 learners. French native speakers showed a P600 effect in response to gender concord errors, suggesting that grammatical gender is processed at the syntactic level in line with previous studies (Hagoort et al., 1993, Osterhout & Holcomb, 1992). While some of the L2 learners (N=4) showed a native-like P600 effect, the majority presented an N400 effect to the same grammatical violations. The ERP signature for the L2 learners suggests that some of the participants were in the process of acquiring gender agreement while others had already acquired the grammatical rule. Osterhout et al. (2006) suggested, based on an N400 response to subject-verb agreement violations, that novice L2 learners may use a chunking strategy by memorizing lexical forms including their morphological inflections, but subsequently are able to grammaticalize an abstract morphosyntactic rule. Our results call this “chunking” strategy into question; none of the noun-adjective pairs we used were likely to have been previously encountered, unlike the subject-verb cases. Nonetheless, the N400 we find to grammatical violations is indeed in line with a stage of “early” grammaticalisation. Furthermore, identification of ERP patterns in L2 learners may allow us to understand developmental trajectories in the process of acquiring grammatical structures in L2.

53. Influence of linguistic context and modalities on the switching mechanism in late Dutch-Portuguese bilinguals. M. Soto (1), A. Improta França (2). (1) Federal University of Rio de Janeiro, ACESIN, Rio de Janeiro, Brazil. (2) Federal University of Rio de Janeiro, ACESIN, Rio de Janeiro, Brazil.

Innovative neuroscientific experiments under the scope of Distributed Morphology (DM) [1,2] investigate claims about the micro-modular architecture of the Language Faculty: words are derived in a distributed fashion. First, abstract syntactic features - root and a categorizing morpheme - are combined. Subsequently, vocabulary items with phonological form are inserted according to the syntactic specifications. Finally, the structure is paired to a content stored in the Encyclopedia and then interpreted by the logical-semantic interface [3,4]. Only in this first cycle a saussurian arbitrary form-meaning matching occurs; in subsequent cycles other morphophonological layers might be inserted, which then are assigned compositional readings. This theory poses interesting questions for the bilingual brain: (i) how is the neurological architecture of the two bilingual language systems organized; (ii) granted the strong distributional assumptions can part of the system be shared between languages; (iii) if so, how does this sharing interfere with word-level processing. In this study, a priming paradigm ERP experiment is applied to late Portuguese-Dutch bilinguals. We varied language combinations (L1-L2;L2-L1;L1-L1;L2-L2) of prime and target, aiming to detect the switching mechanism at different stages of lexical access. Thus, we might verify which modules are shared and which are language specific by observing switching cost usually associated to activation/inhibition patterns [5]. We also manipulated

the modality of the prime: audio, written or picture, whereas the targets were always written. With the behavioral data collecting nearly completed, data seem to confirm known effects for directionality [6], as reaction times (RTs) for L2 to L1 priming are significantly faster than those for L1 to L2 across modalities. The latter combination is slower than L2 to L2 priming, while there seems to be no significant difference between L1 to L1 and L2 to L1 priming. A specific pattern may be observed in comparing different modalities irrespective of different language combinations; written primes lead to faster RTs compared to audio and image primes between which there is no significant difference. For L1-L2 and L2-L2 combinations this difference reaches significance. The fact that RTs for picture primes are similar for both L1 to L1 and L2-L1 suggests that, taking the picture prime to be a language neutral stimulus, late bilinguals maintain a L1 default for language processing. References: [1] PYLKKÄNEN, L; MARANTZ, A. Tracking the time course of word recognition with MEG. *Trends in Cognitive Sciences*. 2003; 7:187–189. [2] STOCKALL, L; MARANTZ, A. A single route, full decomposition model of morphological complexity: MEG evidence. *The Mental Lexicon* 1:1, 2006 [3] HALLE, M.; MARANTZ, A. Distributed morphology and the pieces of inflection. In: HALE, K.; KEYSER, S. J. (Eds.) *The View from the Building 20*, Cambridge, MA: MIT Press, 1993, p. 111-176. [4] MARANTZ, A. No escape from syntax: don't try morphological analysis in the privacy of your own lexicon. *Proceedings of the 21st Annual Penn Linguistics Colloquium*, Philadelphia, 1993, p. 201-225. [5] COSTA, A.; SANTESTEBAN, M.; IVANOVA, I. How do highly proficient bilinguals control their lexicalization process? Inhibitory and language-specific selection mechanisms are both functional. In *Journal of Experimental Psychology, Learning, memory and cognition*, 2006, Vol.32, No.5, p.1057-1074 [6] FELDMAN, L.B.; LARABEE, J. Morphological facilitation following prefixed but not suffixed primes: lexical architecture or modality-specific processes? In *Journal of Experimental Psychology, Human perception and Performance*, 2001, Vol.27, No.3, p.680-691

54. Socio-Cultural Variables Associated with Second Language Learning. A. Garcia-Sierra (1), M. Rivera-Gaxiola (1), Lindsay Klarman (1), B. Conboy (1), S. Ortiz (2), M. Rodriguez (2), N. Wicha (2), H. Romo (2), and P. Kuhl (1). (1) University of Washington, Seattle, US (5) University of Texas at San Antonio, San Antonio, US.

The present investigation explores the relation between infants' socio-cultural environment, their early brain responses to speech, and the children's later language abilities. The brain measures (Event Related Potentials or ERPs) of 15 infants raised bilingually were taken between 9 to 11 months old and correlated with later language abilities at 18 and 24 months old. The early brain measures assessed infants' neural discrimination of the sounds from each of the two languages (Spanish and English) infants heard in their homes. The brain measures showed that, unlike 12-month-old infants raised in monolingual English homes, 12-month-old Spanish-English bilingual babies show neural discrimination of both Spanish and English. Moreover, the brain measures of discrimination taken in infancy were significantly correlated with socio-cultural factors in infants' environments (parents' relative skill at the two languages). Furthermore, infants whose brain responses were relatively stronger to English or to Spanish in infancy showed that same pattern of relative dominance in their production of first words at 18 months. Infants whose brains responded more strongly to differences in Spanish sounds as babies produced significantly more Spanish than English words at 18 months. Similarly, infants who responded more strongly to English sound differences as babies produced significantly more English than Spanish words at 18 months. Infants who as babies responded equally strongly to Spanish and English sound differences produced equal numbers of words in the two languages as toddlers. These results advance our knowledge of bilingual language development by providing brain measures of bilingual development. Moreover, they demonstrate the benefit of longitudinal studies triangulating measures of the parents' language skills and their attitudes towards the importance of bilingual language abilities, the child's early brain responses to speech, and the child's eventual abilities to use words in their two languages. The results support the idea that linguistic experience produces neural networks dedicated to the acoustic properties of the language(s) to which infants are exposed, and highlight the importance of the child's socio-cultural environment on future language development. The present study is pioneer in the sense that examines the relation between early bilingual infants' brain responses to speech and language development longitudinally.

55. Cerebral correlates of second language pronunciation "talent": An fMRI investigation. S Reiterer (1,2) X Hu (2,1) M Erb (1) G Rota (3,4) M Jilka (3) W Grodd (1) H Ackermann (2). (1) University Clinic of Tübingen, Tübingen, Germany. (2) Hertie Institute for Clinical Brain Research, Tübingen, Germany. (3) Institute for Natural Language Processing, Stuttgart, Germany. (4) University of Pisa, Pisa, Italy.

Introduction: There is increasing interest in individual differences in skill acquisition, including second language (L2) learning. Among the factors influencing L2 proficiency, the aspect of "talent" or language aptitude has found only sparse attention so far. And – apart from a few exceptions (e.g., Diaz et al. 2008; Golestani et al. 2007; Amunts et al. 2004) – the neural basis of language aptitude has not yet been investigated by means of brain imaging techniques. Using functional magnetic resonance imaging (fMRI), this study focuses on the cerebral correlates of a distinct subcomponent of the L2 learning talent, i.e., pronunciation ("accent"). Methods: Tape recordings were obtained from 138 German-speaking subjects during imitation of sentences in a language they had no experience with, i.e., Hindi. Using an internet rating database (for further details see Jilka in Dogil & Reiterer 2009), 30 native speakers living in India were then asked to evaluate the "goodness" of spoken language imitation. Sixty out of the total group of 138 participants underwent fMRI during foreign (L2=English), unknown (L0= Tamil) and native (L1=German) spoken language imitation (1.5 T scanner, sparse sampling paradigm; TR = 12s). Using SPM5, the fMRI data from the 10 participants with the highest ("high talent group") and the lowest scores ("poor talent group"), respectively, were compared to each other. Results: Group analyses (main effects vs. baseline, group vs. group contrasts,

random effects model) revealed significant differences in hemodynamic activation between individuals with high and poor pronunciation talent at the level of peri- and intrasyllabic cortex, supplementary motor area (SMA), and cerebellum (Fig.1). More specifically, the "high talent group" showed a more restricted pattern of hemodynamic responses – concomitant with reduced activation maximum – within these areas of the speech motor control network (see Ackermann & Ziegler 2009). Furthermore, direct comparison of the "low talent" versus the "high talent" group yielded significantly higher hemodynamic responses within left middle and inferior frontal areas (Broca) as well as left insula and right superior temporal gyrus. This differential pattern of hemodynamic activation emerged under all experimental conditions (L1,L2,L0), but was found more pronounced during "sentence imitation" as compared to "word imitation" tasks. Conclusions: The obtained fMRI data indicate good pronunciation skills ("pronunciation talent") to be associated with less extensive and less pronounced hemodynamic responses across the cerebral structures supporting speech motor control mechanisms. Most presumably, these differences can be interpreted in terms of the cortical efficiency hypothesis (see Dogil & Reiterer 2009). References: Ackermann H & Ziegler W. Brain mechanisms underlying speech motor control. In: WJ Hardcastle & J Laver, eds. *The Handbook of Phonetic Sciences*, 2nd ed. Malden, MA, in press. Amunts, K et al. *Brain Lang* 2004;89:346-353. Diaz B et al. *PNAS* 2008;105:16083-16088. Dogil G, Reiterer S (eds). Mouton, Berlin, in press. Golestani N et al. *Cerebral Cortex* 2007;17:575-582

56. Does semantics help or hurt syntactic processing in late second language learners?: An ERP study. Y. Yamada (1), H. Neville (1). (1) University of Oregon, Eugene, US.

Event-related potential (ERP) studies of sentence comprehension in second language (L2) learners have repeatedly reported that a more automatic, early stage of syntactic processing indexed by anteriorly distributed negativities (e.g. LAN) is more vulnerable to delay in language acquisition than later, more controlled processes indexed by posterior positivities (e.g. the P600). In contrast, semantic processing indexed by the N400 does not qualitatively differ between native speakers and late learners. A few recent studies examined whether and how lexical semantics affects syntactic processing in adult learners of miniature Japanese. One study (Mueller et al., 2008) reported that, when they were trained on syntactic rules without semantic content, adult learners showed more native-like ERP responses to the syntactic violations in the miniature Japanese than when they were trained on both syntax and semantics. Another study (Mueller, 2009) investigating the effects of the familiarity of lexical items on syntactic processing in late learners of the same miniature Japanese reported that syntactic violations in sentences with unfamiliar open-class words (i.e., without semantic content) elicited less native-like responses than violations in sentences with familiar words. These results suggested that the absence of semantic content hinders learners from engaging in native-like syntactic processing when they were trained in both syntax and semantics. However, because no native Japanese speakers were examined in this study, whether native speakers show similar alterations in syntactic processing as a function of semantic context as adult learners could not be directly assessed. Thus, the available evidence to date is inconclusive regarding the effects of the presence or absence of semantic content on syntactic processing in late learners. In the present study, this question was investigated further in late learners of a full natural language (rather than a miniature language) and by comparing the effects observed in late learners to those found in native speakers. Japanese late learners of English and monolingual native English speakers who were matched on standardized measures of receptive grammar were presented with normal English and Jabberwocky sentences in which syntactic structure was retained but all open-class words were replaced by meaningless pseudowords. Half of both types of sentences contained phrase structure violations. In native speakers, violations elicited an earlier anterior negativity and a later positivity (P600) in both English and Jabberwocky sentences. In late learners, a P600 was elicited in both sentence types. Additionally, the late learners also displayed the earlier negativity for violations in Jabberwocky sentences. However, this negativity was not confined to the anterior scalp region. Thus, the current results, together with the earlier finding from the semantic-free training study, suggest that the absence of semantic content enables late learners to engage in the early stage of syntactic processing. However, the differences in the distribution of this negativity suggest that the processes occurring at this early stage are not identical in native speakers and late learners.

57. Time-course of activation of lexical and conceptual information across languages: An event-related potential study of Chinese-English and Spanish-English bilinguals. M. Misra (1), T. Guo (2), J. W Tam (3), and J. F. Kroll (3). (1) Department of Communication Sciences and Disorders, The Pennsylvania State University, University Park, US (2) State Key Laboratory of Cognitive Neuroscience and Learning, Beijing Normal University, China (3) Department of Psychology, The Pennsylvania State University, University Park, US.

Evidence suggests that less-proficient bilinguals rely on lexical links between words in their second language (L2) and translation equivalents in their first language (L1), while more proficient bilinguals develop the ability to access concepts more directly from L2 words (e.g., Kroll & Stewart, 1994). Specifically, results from experiments in which bilinguals determine whether two words are translations of each other show that skilled bilinguals are sensitive to interference from semantically related distractors, while less skilled bilinguals show interference from distractors related in form to the correct translation but not the meaning (e.g., Sunderman & Kroll, 2006). Thus, a skilled Spanish-English bilingual might show slowed reaction times and reduced accuracy for the word "mujer", which means "woman", when asked to determine if it is the translation for "man". However, a less skilled bilingual might show interference from the word "hambre", which is similar in form to the correct Spanish translation for "man" ("hombre"), but which means "hunger". The current work utilizes event-related potentials (ERPs) and behavioral measures to evaluate the time-course of activation of lexical and conceptual information in a translation recognition task performed by relatively skilled bilingual English speakers whose native language either shared the same script

with their second language (Spanish) or did not (Chinese). Two groups of bilinguals were tested since recent research has suggested that bilinguals whose two languages do not share a script may rely on direct translation equivalents even after becoming proficient L2 speakers (Thierry & Wu, 2007). Results revealed effects of both lexical and semantic interference on behavioral and ERP measures for all participants, regardless of language pairing. Behavioral effects were in the form of slowed reaction times and decreased accuracy as compared to matched controls. While previous behavioral studies with bilinguals at this level of L2 proficiency have not shown large effects of lexical form, the use of a fairly long (750 millisecond) stimulus onset asynchrony between the L2 and L1 word may have encouraged activation of the translation equivalent. ERP effects for the semantic distractors showed an attenuated N400, suggesting that the related word eased semantic integration of the target despite the apparent inhibition revealed in the behavioral effects. Translation/form distractors resulted in an enhanced P200 and enhanced positivity after the N400, with only small effects on the N400 component itself. The lack of strong effects on the N400 from the translation/form distractors supports claims that lexical links are not used to mediate access to meaning in these bilinguals. These results suggest that both lexical and conceptual information may impact processing in skilled bilinguals, although the processes underlying each type of effect, and the time-course of activation (and interference from) each type of information differs. Results have implications for models of bilingual word recognition and are compatible with interactive models positing activation across lexical and conceptual levels for even highly proficient bilinguals.

58. Language use affects semantic and repetition priming in child bilinguals: Evidence from ERP's.

A. E. Hernandez (1), M. Gaebler (1), M. Gugler (1), and I. Wartenburger (1). (1) University of Huston, Houston US.

The present study investigated and examined the effects of language use on neurophysiological activity during auditory word recognition. Previous studies have found that adult bilinguals show greater priming from a stronger to a weaker language. However, to date no study has investigated how language exposure or use affects semantic and repetition priming in early simultaneous bilingual children. To examine this, a group of early German-English bilingual children, ages 6 to 7, who learned both languages from birth and were currently living in Germany were tested. Participants were asked to listen passively to auditorily presented words presented while EEG activity was being monitored. Words were presented in separate English and German Blocks. Within each language block target words were presented twice with varying lags between repetitions. In addition, translations of these words were presented a second and third time in the opposite language in another block. Results revealed an N400 for all words presented with a clear asymmetry in both within- and between-language conditions. In the within-language condition, the N400 was reduced for the second presentation of a word in the German condition but not in the English condition. An asymmetry was also observed in the between-language condition. A reduction in the N400 was observed upon the second instance of a repeated English word when it had been preceded earlier in the experiment by its German translation. However, this effect was not present when a repeated German word was presented after its English translation. Taken together our results suggest that implicit lexical priming of words only occurred when children listened to words in German during the first instance. These results suggest that immersion in a language modulates the magnitude of lexical processing for auditorily presented words. The findings are consistent with the view that lexical-semantic processing in bilingual children, even those who exhibit high proficiency in two simultaneously learned languages, are sensitive to factors such as language use. Recent studies in our laboratory have found that language use during childhood and adolescence modulates neural activity in early adult bilinguals. Taken together these results support an emergentist framework which views childhood language use as being modulated to a greater extent by sensorimotor processing.

59. Monolingual and bilingual 6-8 year old children display N400 responses differentially mediated by proficiency and age of acquisition.

A. Andersson (1), J. Fanning (1), and H. Neville (1). (1) University of Oregon, Eugene, US.

Previous event-related potential (ERP) studies have consistently found an N400 effect elicited by violations of semantic expectancy in monolingual adults (Kutas & Hillyard, 1980), bilingual adults (Weber-Fox & Neville, 1996) and monolingual children (Holcomb, Coffey, & Neville, 1992). In adults, when the second language is acquired before the age of 11 years, no differences are found in the amplitude, latency, or distribution of the N400 effect when compared to monolinguals. However, if the age of acquisition (AOA) is later than 11 years, an increase in peak latency is often reported (e.g. Weber-Fox & Neville, 1996). Studies of semantic processing in monolingual children have found a more widely distributed N400 effect compared to monolingual adults'. In addition, both the amplitude and onset latency are found to decrease with age (Holcomb, Coffey, & Neville, 1992). In order to begin investigating the factors important in establishing normal semantic processing in bilinguals, we compared the N400 responses to semantic anomalies in 6-8 year old monolingual English speakers and in native Spanish speaking children who began acquiring English at about 4 years of age. To examine the effects of proficiency, each group was divided into higher and lower proficiency groups. In addition bilinguals and monolinguals individually matched on age and proficiency were compared. ERPs were recorded while children listened to naturally spoken English sentences that were either canonical or that were semantic anomalies ($p = .5$) and watched an accompanying claymation movie. Analyses of the N400 mean amplitude indicated a typical N400 response for both groups, though that of monolingual children was larger, more widespread, and had an earlier onset (180msec) in comparison with that of bilingual children (320msec). Though these children were matched on age they differed in proficiency (Receptive Language) and Socioeconomic status (SES; as measured by maternal education). When dividing children by proficiency within each group similar relationships with amplitude, distribution, and onset were found. (Higher and lower proficiency bilingual groups did not differ on AOA). When comparing

monolingual and bilingual children that were individually matched on age and proficiency, N400 onset latency was similar (320msec) but the distribution differed across groups. More specifically, monolingual children showed a larger and more widespread effect that was largest over medial central sites while bilingual children had an effect that was largest over posterior sites. These results suggest that speed of semantic processing in children between 6 and 8 years of age is affected by proficiency rather than AOA, while the distribution of the effect could be affected by differences in AOA and/or SES across groups. No differences in the N400 effect are found comparing monolingual adults and bilingual adults who began acquiring their second language before age 11 (Weber-Fox, & Neville, 1996). Therefore, we are continuing to study the development of semantic processes indexed by the N400 in bilingual children in order to determine at what proficiency level and/or years of experience of the second language does the difference between monolingual and bilingual late learners disappear.

Reading and Writing

60. Phonological monitoring failure? ERP evidence for a late stage phonological integration deficit in developmental dyslexia. *N. Savill (1), G. Thierry (1). (1) Bangor University, Wales, UK.*

Recently, the role of weak phonological representations hypothesised to underlie phonological processing deficits in developmental dyslexia has been questioned (Ramus & Szenkovits 2008; see also Banai & Ahissar, 2006). The aim of the present study was to characterise the time range of the phonological deficit in a visual word priming context. Previous electrophysiological studies testing normal readers on visual word tasks have shown differences in phonological processing approximately 250ms after stimulus onset (e.g. Grainger, Kiyonaga & Holcomb, 2006; Simon, Bernard, Largy, Lalonde & Rebai, 2004). If the phonological deficit in dyslexia is indeed attributable to deficient phonological representations, event related potentials (ERPs) elicited during a phonological task ought to reveal earliest group differences within the same time range. We recorded ERPs for 16 adults diagnosed with dyslexia (7 males, 9 females; mean age 21.60 years) and 16 age-matched controls (7 males, 9 females) whilst they performed a pseudoword-word priming task ("do the two stimuli sound the same?") Across all stimulus pairs, phonological similarity (homophonic match, P+/mismatch, P-) and orthographic similarity (orthographic neighbour, O+/non-neighbour, O-) were manipulated to generate four priming conditions (P+O+, P+O-, P-O+, P-O-). Neighbourhood density and length of pseudoword stimuli was controlled. Critically, the target words were the same in all conditions; therefore any ERP differences between conditions could only be attributed to differential priming effects between conditions rather than to the specific items tested. ERPs elicited by target words showed the expected main and interactive effects of phonological and orthographic priming on N2 and P3. As expected, N2 amplitude was significantly reduced by phonological priming and peaked earlier, whereas P3 mean amplitude was significantly increased by both phonological and orthographic priming, which were also found to significantly interact. Phonological priming also modulated P3 peak latency, with P3 peaking significantly earlier with P+ trials. Interestingly, there were no significant group differences in terms of phonological priming up to this point. However, amplitude analyses in the P600 range revealed a significant group by priming interaction: Whilst the control group showed clear P600 differentiation of the four conditions, the dyslexic group displayed a substantially attenuated P600. Analyses of priming effects on P600 latency showed a consistent pattern of earlier peak latency for phonological priming. An interaction of phonological priming with group indicated relatively reduced effects of phonological priming with respect to P600 latencies of the dyslexic group. Since P600 modulations are classically associated with monitoring and reanalysis, we suggest that poor phonological task performance in adult dyslexic readers may arise from inefficient engagement in phonological monitoring, possibly related to specific working memory updating and phonological reanalysis, rather than poor online phonological processing capacity.

61. Phonology is full and fast in visual word recognition: evidence from ERPs. *J. Ashby (1), J. Kingston (2), L.D. Sanders (3). (1) Central Michigan University (2) University of Massachusetts, Amherst (3) University of Massachusetts, Amherst.*

Phonology is full and fundamental in skilled word recognition Three decades of research converge on the importance of phonological awareness in early reading development, yet the role of phonological activation in skilled reading is still under investigation. Recent eye movement studies of word recognition during silent sentence reading indicate that readers of English process several aspects of a word's phonological form, including suprasegmental and subphonemic feature information. A recent MEG study (Cornelissen et al., 2009) found that activation in the left-inferior frontal gyrus was greater for words than consonant strings, peaking around 130 ms. The present event-related potential studies investigated when skilled readers activate complex, sub-lexical phonological information in visual word recognition. Four ERP experiments investigated the time course of full phonological activation by using a masked priming paradigm and visually-matched, within-subject designs. Primes were presented for 44 ms in a four field masked priming paradigm. Participants read single words silently and made semantic decisions to filler items. ERPs were computed for the target items. Experiments 1 and 2 investigated suprasegmental activation by presenting prime-target pairs with either the same first syllable (e.g., ##### - ma### - ##### - MAGIC) and pairs with one letter more or fewer (e.g., ##### - mag## - ##### - MAGIC). Target words were matched for initial trigram but differed in initial syllable structure (e.g., ma.gic and mag.net). Participants saw the identical prime in the congruent and incongruent conditions (ma### - MAGIC; ma##### - MAGNET), with half the items presented in each condition. The congruent prime-target pairs elicited a significantly reduced N1, as compared to the incongruent prime-target pairs. This result indicates that skilled readers begin processing suprasegmental phonological information early in word recognition. Experiments 3 and 4 investigated subphonemic feature activation using prime-target pairs that were congruent or incongruent with respect

to final consonant voicing (e.g., fap- FAT and faz-FAT). Participants saw the identical prime in the congruent and incongruent conditions (fap - FAT; fap -FAD), with half the items presented in each condition. Feature congruency began modulating the amplitude of brain potentials by 80 ms in both experiments, with the feature congruent condition evoking less-negative potentials than the feature incongruent condition. This result indicates that skilled readers begin processing subphonemic phonological information early in word recognition. In sum, these experiments found neurophysiological evidence for complex phonological activation in the initial moments of visual word recognition. The observation of phonological congruency effects in the N1 component indicates that sub-lexical phonological activation is fundamental to word recognition and suggests that skilled readers activate full and detailed phonology in the course of silent reading. This may help account for the severe impact of phonological processing deficits on reading development.

62. A stimulus-driven network for text comprehension. Z.V.J. Woodhead (1), and R.J.S. Wise (1,2). (1) MRC Clinical Science Centre, Imperial College, London, UK (2) Division of Neuroscience and Mental Health, Imperial College, London, UK.

Functional imaging studies of text reading have identified a frontotemporal network that is preferentially activated by meaningful sentences over strings of unconnected words. This network includes the left inferior frontal gyrus (IFG), the left posterior superior temporal sulcus (pSTS), bilateral anterior temporal cortex (ATC) and bilateral middle temporal gyrus (MTG). Such text comprehension studies typically use elegant manipulations of sentence stimuli or task demands to identify the component processes involved in text comprehension. Whilst this strategy may allow the isolation of the specific semantic, syntactic and integrative functions within the network, it can be vulnerable to the potential confounds of task difficulty, response selection, error monitoring or working memory load. This is especially true in the left IFG, which has been implicated in numerous general cognitive functions as well as language-specific ones. In this study we aimed to identify areas that demonstrate preferential activation for meaningful text comprehension in a passive reading task with no explicit task. An event-related fMRI design was used. In each trial, three words were presented in rapid succession (500ms per word, 100ms ISI). The words formed either a meaningful sentence ('his team scored') or a semantically and syntactically implausible word string ('count lay cheese') created by shuffling words from the meaningful sentence stimuli. Resting and number decision baselines were used: the latter maintained the participants' attention throughout the (otherwise 'passive') scanning procedure. The participants (n=15, 8 female) were naïve to the study design and were instructed only to read the words silently. By eliminating task demands, minimising trial length and randomising condition order in an event related design, we avoided the potential confounds of response selection, working memory load and attentional bias between the conditions. We identified regions with significant activation for sentences over random word stimuli in the left ventral inferior frontal cortex; the left posterior MTG; and the right mid MTG. These findings were largely consistent with our predictions, with the notable omission of the ATC. This study demonstrates that a number of the regions identified by previous studies of text comprehension are activated even when stimuli have simple semantic content and syntactic structure, and without an explicit task. This suggests that these regions are involved in stimulus-driven semantic or syntactic processing that is automatic in nature. It is also noted that the implicit nature of the task make it suited to investigating text comprehension processes in patients with reading disorders, where task difficulty is a critical issue.

63. The neural basis of obligatory decomposition of suffixed words: Tracking the “broth” in “brother”. G. Lewis (1), A. Marantz (1), and O. Solomyak (1). (1) New York University, New York, US.

Objective: We investigated the influence of word form properties on early processing stages of complex word recognition. Masked priming studies indicate that affixed words (e.g., worker) and pseudo-affixed words (e.g., brother) activate visual word forms of the stem and affix prior to lexical access. The (masked) word brother will prime the overt target word broth despite the lack of a semantic or morphological relationship (Rastle & Davis, 2008; Rastle et al., 2004). We previously found that morphological decomposition is reflected in the response from the visual word form area (VWFA) in a lexical decision task about 150ms post-stimulus onset (the MEG M170) (Solomyak & Marantz, 2008, in press). Our study focuses on this response in determining the effect of pseudo-affixed word properties on brain activity associated with morphological decomposition. Methods: MEG data were recorded as 11 subjects participated in a lexical decision task. The stimuli consisted of 72 pseudo-affixed words, 421 filler words, and 571 non-words. Subjects' structural MRIs were used to construct cortically-constrained minimum-norm estimates of the MEG data (MNE). Each subject's cortex was morphed to a standard brain to compute grand average activity over all subjects and trials. Regions of interest (ROIs) were labeled on the standard brain based on activity peaks in the grand average and then morphed back to individual brains. ROI activity was correlated with the following three variables: surface frequency (SF), base frequency (BF), and transition probability (TP). Stimulus variables were orthogonalized via a PCA prior to correlational analyses. Results: VWFA analyses were on ROI activity averaged over the time window of 150-200ms. Correlations revealed significant effects of all three variables on VWFA activity. Higher values of SF and TP (the chance of encountering a word given the base) elicited stronger M170 activation, while higher BF was associated with weaker M170 activation. Activity from 200-500ms in the middle and superior temporal regions (the MEG M350) has been associated with lexical access. Correlation analyses on M350 ROI activity between 200-400ms showed significant effects of BF, with higher BF values associated with weaker activation (significant correlations at ~250ms and ~375ms $p < 0.05$ corrected for multiple comparisons). Correlations between response time and each of the three linguistic variables yielded only a facilitation effect of SF. Conclusions: The TP effect for pseudo-affixed words at the VWFA parallels the effect found for morphologically complex words in Solomyak and Marantz (in press) and supports obligatory decomposition hypotheses, as does the “base” frequency

effect at the M350. The SF effect at the VWFA, not found for true affixed words, may be evidence for dual route processing of pseudo-affixed words. Discussion of significance: This study provides direct neural evidence for the conclusions from behavioral masked priming that pseudo-affixed words are obligatorily decomposed at early stages of word recognition, prior to lexical access. Surface frequency effects at the VWFA point to dual route processing for these words. The BF effects are not predicted by models of word recognition and should lead to refinements in these models.

64. Neural correlates of early and late orthographic neighborhood size effects in the reading of Chinese characters: A single-trial correlational MEG study. C.-H. Hsu (1) A. Marantz (2). (1) National Yang-Ming University, Taipei, Taiwan. (2) New York University, New York, US.

Main issues: ERP studies suggest a two-stage framework to account for "orthographic neighborhood" (N) effects: more orthographic neighbors facilitate word processing at the orthographic level due to larger orthographic activation, yielding less positivity at the P200. Then, a larger N size increases semantic competition, exaggerating the negativity at the N400. However, it is still unclear whether the P200 and N400 are mediated by different mechanisms or reflect one temporally-prolonged effect. The presented study uses MEG measurements, which allows for better source separation than EEG, to elucidate the underlying mechanisms of earlier and later effects of N size. Methods: 10 native Chinese speakers participated in a lexical decision task with simultaneous MEG recording. The stimulus set consisted of 400 real characters, 280 pseudo-characters, and 120 non-characters. Subjects' structural MRIs were used to construct cortically-constrained minimum-norm estimates of the MEG data. The cortex of each subject was morphed to a standard brain to compute the grand average activity over all subjects and trials. Regions of interest (ROIs) were labeled on the standard brain based on activity peaks in the grand average, and then morphed back to individual brains. Two ROIs were selected for analyzing earlier MEG responses: (1) negative activity during 100-300ms in left inferior frontal regions (IFG); (2) positive activity during 100-300ms in left posterior-inferior parietal regions (pIPG). Two ROIs were selected for analyzing later MEG responses: (3) negative activity during 300-500ms in the left middle and superior temporal regions (the M350 response, associated with lexical access); (4) negative activity after 300ms in the left anterior-inferior parietal regions (aIPG, associated with recognition memory). ROI activation over a 100ms time window centered at each subject's individual peak latency was correlated with the following three variables: ratio of noun-to-verb frequency (NVratio), phonetic combinability (PCOM) and semantic combinability (SCOM). Combinability of phonetic and semantic radicals is defined as the number of characters that share the same phonetic or semantic radical, respectively (Feldman and Siok, 1997). There are no significant correlations among these variables. Results: For earlier MEG responses, characters with large PCOM were associated with weaker pIPG activation, but characters with higher NVratio were associated with stronger IFG activation. For later MEG responses, characters with large SCOM were associated with stronger aIPG activation. In addition, characters with higher NVratio were associated with weaker M350 response. Conclusions: As previous fMRI studies suggested that the IPG is involved in character recognition, the present results demonstrated that pIPG and aIPG may contribute to earlier and later effects of N size, respectively. It has been suggested that left pIPG plays a role in exogenous adjustment in task switching. Therefore, the combinability effect in pIPG seems to support Grainger and Jacobs' (1996) assumption that N size would modulate the response strategy during lexical decision. On the other hand, competition associated with recognition memory may account for later effects of N size. Discussion of significance: This study confirms the conclusion of earlier ERP work and supports the distinction between early (P200) and late (N400) orthographic neighborhood effects.

65. A cluster analysis of individual differences in reading skill and behavioral lateralization: Associations with structural asymmetries. C. Chiarello (1) S. Welcome (1,2) C. Leonard (3). (1) University of California, Riverside, Riverside, US (2) University of Western Ontario, London, Canada (3) University of Florida, Gainesville, Gainesville, US.

Objective: There is substantial variation in reading skill, even among college students, but the relationship of this to variation in cortical anatomy and lateralization is unclear. Previous approaches have investigated differences between a priori groups (sex, handedness), with conflicting results. However, such groups may not reflect distinct behavioral subtypes that exist within the population of normal readers. Here we identify groups in a bottom-up fashion by patterns in their behavioral data. Our objective is to identify common variants in the relationship between reading skill and behavioral lateralization, and to examine neuroanatomical correlates. Methods: The Biological Substrates for Language Project gathered demographic and reading test data, and divided visual field (VF) asymmetries (RT and accuracy), from 200 college students who also received a structural MRI scan. The following uncorrelated measures were used in the cluster analysis (Ward's method): word attack; accuracy asymmetry for masked word recognition, lexical decision, and verb generation; RT asymmetry for nonword naming, masked word recognition, lexical decision, and verb generation. Surface areas of several language relevant regions were measured from left and right sagittal MRI sections. Results: A four-cluster solution (eigenvalue =.97) successfully classified all but 17 participants. The clusters represented distinctive reading/lateralization profiles (see table), but did not differ in age, sex, or handedness: • relatively poor readers with somewhat reduced RVF advantages (N=61) • average readers with enhanced RVF advantages (N=63) • better readers with reduced asymmetries (N=26) • better readers with task-dependent asymmetries (N=33). By definition, "outliers" (N=17) do not resemble each other on the criterion variables. However, they differed from the clustered individuals on the within-subject consistency (standard deviation) of their task asymmetries - in addition to their atypical reading/lateralization profiles, their asymmetries are more unstable. All clusters displayed robust

leftward asymmetries of the planum temporale (PT) and rightward asymmetries of the planum parietale. However, outliers showed unusual planum temporale asymmetries – over 40% had reversed asymmetries, and the distribution of asymmetries was shifted rightward relative to the clusters (see figure). Significance/Conclusions: Our findings suggest that a variety of reading/lateralization profiles exist among college age readers. We identified several “typical” reading subgroups with differing VF laterality profiles, and normal leftward planum temporale asymmetry. A minority of the sample showed no discernable pattern in the cluster analysis, inconsistent VF asymmetries, and atypical planar asymmetry. This may reflect a less regulated pattern of neural development, in which random genetic and environmental factors influence cerebral lateralization and behavioral outcomes. We conclude that there are individual differences in brain-behavior relationships that are not captured by standard demographic variables.

Reading Skill Poorer Average Good Good OUTLIERS VF Asym Low-to-Average
 Large Low Vary by Task Word Attack % 31.9 47.3 66.2 60.8 55.2 Word ID % 40.7 50.3 57.0 58.6 51.2 Passage Comp%
 56.1 63.7 73.7 73.4 77.2 VF Asymm1 -.212 +.249 -.510 +.163 +.301 Within-S Consistency (.816) (.886) (.803) (.886) (1.44)
 Planum Temporale2 .33*** .30*** .40*** .41*** .13, ns Planum Parietale2 -.43*** -.30** -.73*** -.37* -.50* 1 Asymmetry
 z-score: 0 = average asymmetry; negative = below average asymmetry 2 Coefficient of asymmetry; positive = leftward
 asymmetry; *p=05, ** p=01, *** p =001.

66. Silent Reading: early activation of right frontal gyrus for abstract words. O. Sysoeva (1), A. Ivanitsky (1). (1) Institute of Higher Nervous Activity and Neurophysiology, Russian Academy of Sciences, Moscow, Russia.

Recent studies challenge the timing of written words semantic processing. New evidences suggested that semantic analysis of words is possible already within the 100 ms post-stimulus (Michel et al., 2005). In our previous study (Sysoeva, et al., 2007) it was found that during silent reading, event-related potentials (ERPs) to abstract and concrete words are different already within the first 100 ms post-stimulus. Functional microstates analysis (Cartool) revealed the additional microstate, characterized with right frontal positivity, for the abstract words within this time period. Current study investigated this difference further using high-density 256-channel EEG EGI system with different sets of the words and on different subjects. Sixteen right-handed subjects participated in the study. They gave informed concern when the nature of the study was explained to them. 74 Abstract and 74 concrete written words, equated for word length, word frequency and emotionality were presented sequentially in the middle of the screen in random order. Subjects were instructed to look in the middle of the screen and to read silently the presented words. They were naïve about the category of the words. EEG were recorded with Cz reference and re-referenced with the average referenced. Sampling rate was 500 Hz, filtering 0.1-30 Hz offline. Artifact-free trials, starting 100 ms before and ending 500 ms after stimulus onset, were averaged separately for each stimulus type to obtain event-related potentials (ERPs). T-test for dependent samples was used to compare the ERPs' amplitudes in response to abstract and concrete words separately in each electrode and time point. The LAURA algorithm, implementing in Geosource software (EGI), were used to model in activity of the brain based on the activity recorded from the scalp. The early right frontal differences were replicated in this study (fig.1). Moreover, source modelling technique revealed the additional activation of right prefrontal cortex in response to abstract words (fig.1). This result is in agreement with the some fMRI studies (D'Esposito et al., 1997, Beauregard et al., 1997, Grossman et al., 2002), which found the additional activation in the right frontal areas for the abstract words during the passive viewing task. Our study suggested that the right frontal gyrus activated already at the latency of 70 ms post-stimulus. The early activation of frontal cortex is really unusual for human ERP research, but the recent studies found activation of frontal cortex already by 70 ms after visual stimuli presentation (Foxye & Simpson, 2002, Worden & Foxye, 2003, Blanke et al., 1999). What is the meaning of this early right frontal activation? This does not correspond with Pavio theory about additional “imagestic” system for concrete words. There must be something specific for abstract words processing. Recent studies (Dyunabeitia et al, 2009, Crutch et al. 2005, 2006) proposed different representational principal for abstract and concrete words storage. The difference in abstract and concrete words representation in the brain may be also due to the time and method of these words acquisitions.

67. Expertise for words in the early visual cortex: an fMRI study. M. Szwed (1),(3),(7) S. Dehaene (1),(3),(4),(7) A. Kleinschmidta (1),(3),(7) E. Egera (1),(3),(7) R. Valabrègue (8), A. Amadon (3), L. Cohen (2),(5),(6). (1) INSERM-CEA Cognitive Neuroimaging Unit U562, IFR 49, Gif sur Yvette, France (2) Université Pierre et Marie Curie-Paris 6, Faculté de Médecine Pitié-Salpêtrière, IFR 70, Paris, France (3) CEA, NeuroSpin center, IFR 49, Gif sur Yvette, France (4) Collège de France, Paris, France (5) AP-HP, Groupe hospitalier Pitié-Salpêtrière, Department of Neurology, Paris, France (6) CR ICM, INSERM U975, Paris, France (7) Université Paris XI, Orsay, France (8) CENIR, Université Paris 6, Faculté de Médecine Pitié-Salpêtrière, Paris, France.

Acquisition of reading skills might result from a “recycling” of occipito-temporal circuitry for object recognition into neural networks specialized for visual word recognition. What remains to be determined is which levels of the visual system are actually modified through the acquisition of literacy. The Visual Word Form Area in the fusiform region displays several high-level features associated with reading, such as case- and location-invariance. But words traverse all stages of the visual system, and given what is known about the impact of perceptual learning and expertise, the early visual cortex might also develop preferential tuning for written words. Here we report the results of a high-resolution 3T fMRI experiment (1.5x1.5x1.8 mm voxels, 16 subjects). We used word and object stimuli carefully matched for low-level visual features, and control images made by adequate scrambling procedures that keep the local features intact. Subtracting the activations evoked by those appropriately matched controls allowed us to factor out the remaining low-level visual differences. With such stimuli, areas more active for words than objects can be found at most levels of the ventral visual system. Most interestingly, we found

selectivity for reading in the early visual regions. Surprisingly, areas V1,V2,VP,V4 show more activation for words relative to scrambled words but not for objects relative to scrambled objects. The effect was symmetrical in V1/V2 and left-predominant in VP/V4. In those areas, all subjects studied had higher activations for words than for scrambled words. One could argue that the striking difference in activation pattern between words and objects was a consequence of some low-level geometrical properties specific to words as compared to objects (e.g. stimulus envelope or distribution of spatial frequencies). However, response profiles to pseudo-objects created from the words' features, which share the same low-level features as words were similar to profiles associated with objects. This demonstrates that heightened responses to words in early visual cortex are indeed specific. Also, preliminary results (n=3 subjects) show that preferential tuning for words in early visual cortex can be robustly observed with a variety of fonts (upper- and lowercase), tasks (demanding one-back and easy oddball detection) and experimental designs (block and event-related). We conclude that early visual cortex activations for words are expertise-dependent and a consequence of perceptual learning driven by the strong pressure for fast, parallel processing of words. The impact of literacy on the brain is thus more pervasive than originally proposed.

68. Semantic radical consistency and character transparency effects in Chinese: An ERP study. *I.F.*

Su (1) B.S. Weekes (2). (1) University of Sussex, Brighton, UK (2) University of Sussex, Brighton, UK.

BACKGROUND This event-related potential (ERP) study aims to investigate the representation and temporal dynamics of Chinese orthography-to-semantics mappings by simultaneously manipulating character transparency and semantic radical consistency. Character components, referred to as radicals, make up the building blocks used during reading Chinese characters. These radicals can be further categorized into semantic and phonetic radicals, which encode the meaning and pronunciation of the character to some degree (Chen & Weekes, 2004). The understanding of semantic radicals remains underdeveloped regarding to what extent the character transparency (whether the individual exemplar conveys similar or different meaning to its radical) and semantic radicals consistency (the extent to which a radical consistently represents a specific meaning) affect the identification and categorization of a character. Transparent characters were recognized faster than opaque characters in meaning judgement tasks, however, the effects of consistency are mixed (Chen & Weekes, 2004; Chen et al., 2006; Hsiao, Shillock, Lavidor, 2006). **METHODS** Native Mandarin speakers were asked to judge whether the character presented was a real or pseudo-character in the lexical decision task and whether the word presented were easy or difficult to imagine in the semantic categorization task. The characters varied in semantic transparency (transparent vs. opaque) and radical consistency (consistent vs. inconsistent). **RESULTS** Behavioural results only showed significant effects of transparency, $F(1,26) = 52.20$, $p < .001$, and consistency, $F(1,26) = 27.71$, $p < .001$ in the semantic categorization task, whereby participants were faster to respond to words that had more transparent mappings to their semantic radicals or entailed highly consistent semantic radicals. ERP results showed a significant transparency effect at 300-500ms in centro-parietal regions (N400), $F(1,23) = 4.05$, $p < .05$, where transparent characters elicited larger amplitudes in the categorization task. Significant semantic radical consistency-by-character transparency interaction was also observed at occipito-parietal regions between 200-250ms, $F(1,23) = 4.21$, $p < .05$, and at N400, $F(1,23) = 4.22$, $p < .05$. Semantic radical consistency effects was found for opaque characters in the semantic categorization task where opaque characters with inconsistent semantic radicals elicited reduced amplitudes. **CONCLUSION** The results suggest that the meaning of the semantic radicals can influence early stages of pre-lexical access (at 200-250ms) and later lexical processing as revealed by the N400 when semantic retrieval is required by the task. That is, mappings between semantic radical orthography and semantics can shape access to the meaning of the character. Reduced amplitude for opaque inconsistent characters suggest difficulty in ease of lexical access due to weaker mappings to character meaning representation. These data support the assumption of radicals as input units proposed by the lexical processing model (Taft, 2006) and lexical constituency model (Perfetti, Liu & Tan, 2006) of character recognition. However, the semantic radical consistency – by – character transparency interaction found during pre-lexical access cannot be explained easily within the current frameworks. The possibility of bi-directional mappings between semantic radical orthography and semantics is proposed in conjunction with existing models.

69. Natural reading is different, after all: Evidence from concurrent ERP and eye-tracking measures. *F. Kretzschmar (1), I. Bornkessel-Schlesewsky (2), and M. Schlewsky (3).*

(1) Graduate Program NeuroAct "Neuronal Representation and Action Control" University of Marburg, Marburg, Germany & Department of English and Linguistics, University of Mainz, Mainz, Germany (2) Independent Junior Research Group Neurotypology, Max Planck Institute for Human Cognitive and Brain Sciences, Leipzig, Germany & Department of Germanic Linguistics, University of Marburg, Marburg, Germany (3) Department of English and Linguistics, University of Mainz, Mainz, Germany.

To shed light on the time course of language comprehension, researchers typically measure event-related brain potentials (ERPs) or eye movements (EM). Both techniques are multidimensional and provide detailed timing information. However, it has been pointed out that their results can be contradictory. Specifically, neurophysiological responses thought to index the processing of a particular stimulus dimension are often measurable at a point in time at which the eyes have already reacted to the same information (cf. Sereno & Rayner, 2003). For example, effects of word frequency are reliably observed in the EM record within the first 250 ms after words are fixated (cf. Rayner, 1998), while the most frequently reported corresponding neurophysiological effect (the N400) occurs approximately 100-150 ms later (cf. Kutas & Federmeier, 2000). As the neural processing of a stimulus is clearly a prerequisite for an observable influence on EM, this relative timing between the two methods appears paradoxical. For lexical processing, this timing paradox has led some researchers to focus on pre-N400

ERP effects (cf. Dien, 2009). Yet, while such effects have been observed in several studies, they currently appear considerably less consistent than the well-established N400 response. Hence, the present study adopted a different approach, namely the acquisition of concurrent EEG / EM measures during reading. This allowed us to examine the effect of critical properties of natural reading on ERPs, e.g. the presence of a valid parafoveal preview of upcoming words. We employed an experimental manipulation which is well-established in the ERP domain, namely antonym processing (Kutas & Iragui, 1998; Roehm et al., 2007). In previous (visual and auditory) ERP studies, this type of manipulation (1) yielded a graded N400 effect: antonyms < related words < unrelated words. (1) Example (vertical bars indicate EM analysis regions) Dass schwarz | das Gegenteil von | weiß/gelb/nett | ist, | ... that black | the opposite of | white/yellow/nice | is | ... At the critical region, EMs revealed shorter first fixations for antonyms vs. related/unrelated words (213 vs. 233/226 ms). Later measures showed a similar pattern. The three-way distinction observed in previous ERP studies did not manifest itself in any measure on any region. ERPs time-locked to the first fixation on the critical region showed comparable N400 effects (220-500 ms) for related/unrelated words vs. antonyms. The unrelated condition also showed a late positivity. Strikingly, an analysis of ERPs time-locked to the last fixation in the pre-critical region revealed a further N400 for the unrelated condition, which must be due to a parafoveal preview. There was no concomitant difference in fixation times. These findings suggest that the previously observed N400 gradation was due to the summation of processes, which occur in succession in natural reading (lexical feature preactivation vs. antonymy evaluation). They further demonstrate that visual information is passed on to the neural language system that does not show up in the EM record (perhaps because saccade programming has been completed). In summary, the data suggest a tight two-way coupling of eye movements and neurophysiological measures.

70. The literate brain: The relationship between reading and spelling. *B. Rapp (1) and K. Lipka (1). (1) Johns Hopkins University, Baltimore, US.*

Introduction. Among the central questions in written language research is whether or not reading and spelling share representations and processes. The question is, of course, central to our understanding of the cognitive and neural machinery that supports literacy. Furthermore, because written language involves both comprehension (reading) and production (spelling), it constitutes a domain in which to investigate the general question of the relationship between recognition and production, perception and action, a question investigated in a number of domains (e.g., vision/action; spoken language perception/production). Finally, because written language is a relatively recent human invention, the identification of its neural bases and an understanding how these relate to those of evolutionarily older domains such as visual object and face processing, furthers our knowledge of how human cortex may develop expertise in novel cognitive domains. The majority of the evidence regarding the relationship between reading and spelling has come from individuals with acquired dysgraphia/dyslexia as a result of neural injury. While favoring a shared substrates position, this work has suffered from some of the difficulties of interpretation, preventing definitive conclusions. Additionally, while there have been a large number of neuroimaging studies of reading in neurologically intact adults, there have been a very small number that have considered any aspect of spelling, and none that have included both reading and spelling. We report here on the results of out an fMRI investigation in which both reading and spelling were examined in the same individuals, allowing greater precision in establishing the relationship between the functions. Also examined was the relationship of written language substrates to those involved in face and object (house) processing. Methods and Results. Ten individuals participated in three experimental tasks: (1) passive reading, (2) passive viewing of objects (faces and houses) and (3) an active spelling probe task. Whole brain echo planar images (EPIs) were acquired with a 3.0 Tesla Philips scanner. After standard pre-processing and spatial normalization to Talairach coordinates, analyses of the functional data revealed the following: (1) reading and spelling share neural substrates in two areas: the left fusiform gyrus (-42,-48,-13) and in the inferior frontal junction (-42,3,24); the reliability of the cross-modality spatial overlap at each of these sites is shown to be comparable to within-modality, split-half spatial overlap reliability; (2) written language and face processing show complementary activation patterns in these same regions, recruiting homologous left and right hemisphere areas respectively; (3) a region of frequency-sensitive, modality-independent, lexical processing is identified in the anterior left fusiform. Conclusions. The finding that the perception and production of written language share neural substrates in the left mid-fusiform gyrus expands our understanding of a region that has recently received considerable empirical scrutiny. Furthermore, the specific involvement of the left inferior frontal junction in both passive and active orthographic processing tasks raises questions regarding the functions of this region. Finally, the complementary patterns of neural recruitment by orthographic and face processes suggests a principled accommodation of recently acquired skills within the neural landscape of evolutionarily more basic object and language substrates.

71. Evidence for a common neural substrate of orthographic processing during reading and spelling. *H. Cho (1), S.Z. Rapcsak (1,2), and P.M. Beeson (1). (1) University of Arizona, Tucson, US. (2) Southern Arizona VA Health Care System, Tucson, US.*

Objective: Whether reading and spelling rely on the same orthographic representations has been a controversial issue in neuropsychology. Functional imaging studies of reading have shown activations in the "visual word form area" (VWFA) occupying the mid-lateral portions of the left fusiform gyrus, suggesting that this cortical region may be the neural substrate of the orthographic lexicon (Cohen et al., 2000, 2002). It has been shown that spelling words also activates the VWFA (Nakamura et al., 2000, 2002; Beeson et al., 2003). These findings suggest a central role for the VWFA in orthographic processing and support the view that the same orthographic lexical representations mediate both reading and spelling. There

has been, however, no imaging study to date that explored both reading and spelling in the same group of individuals. The purpose of this study was to investigate whether the cortical region responsible for orthographic processing during reading is also activated during spelling in normal participants. **Methods:** Eleven native English speakers participated in the study. Two block-design fMRI protocols were used. The reading protocol consisted of reading words silently contrasted with viewing checkerboards. The writing protocol consisted of written picture naming contrasted with copying scribbles. A total of three runs (one run for reading, two runs for writing) were administered to each subject using E-prime software. Functional images were acquired on a GE 3T whole-body MRI scanner. Data were analyzed within a region of interest (ROI) confined to left inferior temporo-occipital cortex that encompassed the fusiform gyrus. **Results:** The reading words vs. viewing checkerboards contrast, designed to identify cortical regions involved in orthographic processing during reading, yielded activations within the left fusiform ROI in each individual. The written picture naming vs. copying scribbles contrast, designed to identify the cortical regions involved in the retrieval of orthography during spelling, also yielded activations within the ROI in all the subjects. When reading and spelling were compared, 10 out of 11 participants showed overlapping activation for the two tasks in the neighborhood of the coordinates reported for the VWFA in a meta-analysis of reading studies by Jobard et al. (2003) (Figure 1a). The same comparison of reading and spelling tasks for the whole group of participants also indicated reliable activations near the VWFA (Figure 1b). **Conclusion:** Our results show that the mid-portions of the left fusiform gyrus corresponding to the VWFA are activated during both reading and spelling, suggesting that this cortical region is the common neural substrate of orthographic processing for both written language tasks. Lesion studies have also demonstrated that damage to the left fusiform gyrus in the vicinity of the VWFA results in both reading and spelling impairment or “alexia with agraphia” (Rapcsak & Beeson, 2004). Taken together, these findings provide strong empirical support for the notion that reading and spelling rely on shared orthographic representations.

72. Going beyond the words tested: lexicality effects in fMRI assessed with meta-analysis, subjects/items analysis and min-F's. M. H. Davis (1), L. Meteyard (2), C.-M. Longtin (1), O. Hauk (1), J. Peelle (1), R. Henson (1), I. Nimmo-Smith (1). (1) MRC Cognition and Brain Sciences Unit, Cambridge, UK (2) Division of Psychology and Language Sciences, University College, London, UK.

Functional imaging has shown a number of brain areas that respond differentially to presentation of written words and pseudowords. Elevated temporal and parietal responses to real words might reflect access to the meaning of familiar words, whereas occipital and prefrontal responses to pseudowords may reflect increased emphasis on sub-lexical orthographic and phonological computations for unfamiliar items. However, statistical tests in typical brain imaging studies (except Bedny, Aguirre & Thomson-Schill, 2007, NeuroImage), assess the average responses to all items for each participant (analysis by subjects, F1). As discussed by Clark (1973, JVLVB), this is subject to the “language as fixed-effects fallacy” since tests for significance do not consider variation present in the population of items tested. Existing simulation results would suggest an increased risk of false positives for analysis by subjects only (Rietveld & van Hout, 2007, BRM) and hence recommended psycholinguistic practice is to combine F1 with analysis by items (F2) in order to compute min-F' (Raaijmakers, Schrijnemakers & Gremmen, 1999, JML). Here we apply these procedures to functional imaging data on lexicality effects, comparing results to traditional statistical procedures, and to a meta-analysis of 18 published fMRI studies that compare neural responses to written words and pseudowords (Fig 1a). An event-related fMRI study in which 15 participants made lexical decision responses to 300 written words and 300 pseudowords replicated many of the brain regions that show lexicality effects in previous studies. Subjects analysis revealed additional responses to words in left middle temporal gyrus, anterior fusiform, inferior parietal and rostral frontal regions, whereas elevated responses to pseudowords were observed in left occipito-temporal, bilateral prefrontal regions and SMA (Fig 1b). However, analysis by items (F2) showed a partially-overlapping subset of significant responses when between-item variability was considered (Fig 1c). Word >pseudoword responses were apparent in right MTG, but absent in inferior parietal regions, pseudoword >word responses in lateral occipital regions no longer reached corrected significance. Combining F1 and F2 maps into a Min-F' statistical map further reduces the number of regions that reach statistical significance with only middle temporal responses to words and prefrontal/SMA responses to pseudowords remaining significant (Fig 1d). These findings suggest that important sources of variability have been overlooked by the statistical procedures used in most previous functional imaging studies. Analysis of item-specific response profiles can suggest hypotheses for the function of brain regions such as the inferior parietal lobe that show non-significant responses when item variability is considered. Similarly, between-subject variation might explain our observation of right MTG activation for words in items analysis since this effect was non-significant in conventional analysis by subjects. However, in the absence of significant effects in min-F' analyses, we would encourage caution in drawing strong conclusions from response differences shown only by conventional statistical analysis. Correct treatment of both between-subject and between-item variance is important if functional imaging experiments are to produce results that generalise beyond the population of subjects and items that are tested.

73. Reading mirror-letters and mirror-words: Behavioral and electrophysiological evidence. J. A. Dunabeitia (1,2), N. Molinaro (1,2), and M. Carreiras (1,2,3). (1) BCBL: Basque Center on Cognition, Brain and Language, Donostia, Spain. (2) Instituto de Tecnologías Biomédicas, Tenerife, Spain. (3) University of the Basque Country, Donostia, Spain.

The underlying neural circuits involved in human cognitive processes are established by reconfiguration of preexisting general cerebral mechanisms evolved for other processes common to all primates. For instance, visual word recognition is grounded

on the universal principles that guide the visual system. In this study we examined how visual word recognition is influenced by a general property of the visual system like insensitivity to mirror reversals of objects. Reduced populations of neurons at the human lateral occipital complex are selective for image orientation, and respond to both the original and the lateral mirror versions of an image. It has been repeatedly proposed that in the process of reading acquisition, mirror generalization of letters and words has to be suppressed, and the insensitivity to mirror images has to be inhibited in order to efficiently identify the words and their constituent letters. But, are expert readers really blind to mirror-letters and to words in their mirror version? We tested undergraduate students in a series of masked priming experiments. In Experiment 1, participants completed a lexical decision task to words that were briefly (~50 ms) preceded by mirror versions of the same words. In Experiments 2 and 3 a similar paradigm was followed while event-related brain potentials were recorded. In Experiment 2 target words were briefly (~50 ms) preceded by the same words containing mirror-letters, and in Experiment 3 targets were preceded by the same words presented in their mirror versions. Results showed that when unconsciously perceived, words containing mirror-letters and words presented in their mirror version were processed similarly to words presented in their canonical version. Our data showed that at early stages of word processing, words that included internal letters in their mirror version were processed similarly to the correct words, and differently to words in which those critical letters were replaced by other letters in their mirror version. This mirror-letter effect was mainly evident in the time window corresponding to the N250 component (150-300 ms), which has been typically related to orthographic processing. Also, words presented in their mirror version (completely reversed in a mirror fashion) were processed similarly to those same words presented in their canonical form, and differently to control unrelated strings presented in a mirror version. This mirror-word effect emerged in the N250 time window, but also in a later epoch corresponding to the N400 component (350-500 ms). These data constitute the first empirical demonstration of unconscious reorientation of mirror-letters and mirror-words in a silent reading task. Furthermore, these data show that a general neural property like the tolerance to mirror reversals, cannot be totally suppressed for reading, and that its effect influences early automatic stages of word processing. These results shed some light on the interface between visual word recognition processes and general visual processes, and can help to a better understanding of the functional properties of the neural systems implicated in reading.

74. Sluggish attentional shifting in dyslexic adults: evidence of abnormal brain activity for the processing of rapid sequential stimuli in vision and audition. M. Lallier (1), M.J. Tainturier (2), B. Dering (3), S. Valdois (4), G. Thiery (5). (1) LPNC, Grenoble, France (2) School of Psychology, Bangor, UK (3) School of Psychology, Bangor, UK (4) LPNC, Grenoble, France (5) School of Psychology, Bangor, UK.

Amodal temporal processing difficulties have been implicated in dyslexia (Stein & Talcott, 1999) and hotly debated in the visual modality (e.g. Bretherton & Holmes, 2003). Amongst other hypotheses, Hari & Renvall (2001) argued that these difficulties would be due to a specific parietal dysfunction, through sluggish attentional shifting (SAS) in all sensory modalities (see Lallier et al., in press). Using event related potentials (ERPs), this study aimed to bring the first evidence of an amodal SAS deficit in dyslexia through electrophysiological markers of attentional processing in vision and audition on the same participants. The visual and auditory attentional shifting skills of 13 control adults (20.3 years) and 13 dyslexic adults (19.3 years; phonological disorder associated) were monitored through two similar oddball paradigms involving serial stimuli presentation. We varied the speed at which visual dots (or auditory tones) alternate between two locations (or two auditory frequencies). Three stimulus onset asynchronies (SOAs) were chosen leading to a standard 'slow' alternation pace (SOA = 340ms) and two deviant paces, i.e. 'fast' (SOA = 90ms) and 'moderate' (SOA = 176ms). Analyses on the mean amplitude of the components elicited by the two deviant paces were conducted over medial parietal electrodes (audition: 250-400ms positive component; vision: late positive component). In both modalities and groups, the electrophysiological differences between the 'slow' standard stimulus and the 'fast' deviant stimulus were found to be the same. However, compared with 'fast' deviants, the mean amplitude of ERPs elicited by 'moderate' deviants was found to be significantly more reduced in the control group, for both modalities. Interestingly, the ERP results are in accordance with visual and auditory stream segregation thresholds measured by adaptive procedures in the two populations (Lallier et al., under review). During the 'fast' pace stimulus (SOA = 90ms) the results suggest that the two groups could no longer shift attention fast enough from one stimulus to another, giving the perception of two simultaneous distinct streams. Indeed, segregation thresholds were higher than 90ms whatever the group and the modality. For the 'slow' pace however (SOA = 340ms), one single stream have been perceived. Furthermore, in dyslexic participants, the moderate alternation pace (SOA = 176ms) was close to their segregation thresholds (i.e. visual and auditory SOAs ~ 170ms). This could have only intermittently led them to disengage their attentional focus fast enough from a stimulus to another, resulting in a perceived pattern closer to two simultaneous streams. However, controls participants might have perceived a pattern closer to a single stream due to lower segregation thresholds (i.e. visual and auditory SOAs ~ 130ms) reflecting faster attentional shifting skills. Overall, our results give support to the role of auditory SAS at the neuronal level in preventing adequate phonological representations build-up (Hari & Renvall 2001; Lallier et al., in press). The results of the present study further indicate for the first time that similar SAS may affect the processing of information in visual neuronal pathways.

75. Cerebral reorganization after visuo-attentional training in dyslexic children: An fMRI study. C. Peyrin (1), M. Lallier (1), J.F. Démonet (2), J.F. Le Bas (3) and S. Valdois (1). (1) Laboratoire de Psychologie et NeuroCognition, CNRS UMR5105, UPMF, Grenoble, France. (2) INSERM U825, Hopital Purpan, Toulouse, France. (3) INSERM IFR n°1, RMN biomédicale,

Unité IRM 3T, CHU Grenoble, France.

Developmental dyslexia is commonly associated with phonological processing disorders and a selective dysfunction of the neural mechanisms involved in phonological processing. Specific remediation programs focussing on auditory processing or phonological training can not only improve the reading ability of dyslexic children but also modulate brain activity in those regions underpinning phonological processing. Other studies however showed that some dyslexic individuals suffer a visual attention (VA) span disorder in the absence of phonological problems. The aim of this fMRI study was to assess the effect of an intensive VA training on the cerebral activity of dyslexic children. Twelve French dyslexic children (mean chronological age = 10 years 3 ± 12 months; mean reading age = 7 years 2 ± 6 months) with severe VA span disorders participated to the study. The VA training program included series of exercises that were used daily for half an hour during 6 weeks. The effect of training was investigated at both the behavioural and neurobiological level. Dyslexic children were submitted to neuropsychological tests (including tasks of reading, spelling, phoneme awareness and visual attention) before and after training. Each dyslexic child further participated to two sessions of fMRI acquisition, before and after training. Their cerebral activations were compared to a group of twelve French non dyslexic children (mean chronological age = 10 years 3 ± 18 months) tested in a single fMRI session. During each session, the cerebral substrates related to VA processes were explored to assess specific training effects on cerebral activity using a lateral masking task addressing visual attention processing skills (Fig. 1a). Children had to judge whether two simultaneously presented letters (an isolated central letter and an embedded peripheral letter) were identical or not. FMRI was performed on a Bruker 3T MR imager, equipped with echo-planar (EPI) acquisition. Each paradigm was designed in an event-related mode. Data analyses were performed by using SPM2 (Wellcome Department of Imaging Neuroscience, London, UK, www.fil.ion.ucl.ac.uk/spm). FMRI data acquired from non dyslexic children (Fig. 1b) showed that the lateral masking task activated a large cortical network comprising bilaterally the superior and inferior parietal cortex (BA 7 and BA 39/40), the inferior temporal cortex (BA 37), the striate and extrastriate visual cortex (BA 17/18/19) and the inferior frontal cortex (BA 44/45). For the dyslexic children (Fig. 1c), the data showed that the striate and extrastriate visual cortices (BA 17/18/19) alone were activated before training. However, results obtained after training showed an activation of the superior and inferior parietal cortex similar to non dyslexic children. More interestingly, a direct comparison between the pre- and post-training fMRI sessions revealed a significant bilateral activation increase of the superior parietal cortex (BA 7) and middle occipital cortex (BA 18/19). The changes in brain activity are further associated to specific improvements of performance. The present findings show that specific modifications in brain activation occur following an intensive rehabilitation program of VA processing, leading to reading improvement. These findings thus suggest that VA span abilities causally relate to reading performance in developmental dyslexia.

76. The contribution of the insular cortex to vowel length discrimination in developmental dyslexia. K. Groth (1,3), C. Steinbrink (2) and A. Riecker (3). (1) Transfer Centre for Neuroscience and Learning, University of Ulm, Ulm, Germany (2) Department of Psychology II, University of Kaiserslautern, Kaiserslautern, Germany (3) Department of Neurology, University of Ulm, Ulm, Germany

In developmental dyslexia it is still unsolved whether phonological deficits represent the primary cause or a secondary symptom resulting from impairments in processing basic acoustic parameters of the speech signal. Thus, sensory deficiencies in rapid temporal processing as the underlying mechanism of developmental dyslexia are still under debate. In German, temporal processing can be investigated by means of the vowel system comprising monophthongs, which can be grouped to vowel pairs. These pairs exclusively differ with respect to vowel length (long vs. short), which is characterized by both temporal (duration) and spectral (formant frequency) information. The perception of long or short vowels embedded in word-pairs, like Stahl (/Stɑ:l/, [steel]) and Stall (/Stɑ:l/, [barn]), allows us to determine the words' meaning and orthography. Consequently, in German such differentiation plays an important role. Recent studies support the notion of functional hemispheric asymmetry for auditory temporal processing. The left hemisphere is supposed to predominantly process temporal information extending across a few tens of milliseconds whereas the right counterpart mediates spectral information upon longer time frames. Regarding temporal processing in dyslexia, functional neuroimaging studies indicate that the sensitivity to rapid relative to slow auditory stimuli in the left frontal cortex is disrupted. Especially the anterior insula was identified as an important neural correlate of auditory temporal processing. Therefore, the present study investigated the contribution of the insular cortex to German vowel length discrimination in developmental dyslexia. Seventeen dyslexic and sixteen control subjects participated in an event-related functional magnetic resonance imaging (fMRI) study. Behavioural and neural responses were measured using a discrimination experiment with pairs of CVC (consonant-vowel-consonant) pseudo-word syllables presented via headphones. Syllable-pairs were either identical or differed with respect to their vowel length. Additionally, the utilised vowels were either original (differing temporally and spectrally) or manipulated, so that the vowels of a pair differed exclusively with respect to temporal information while spectral content was kept constant. Participants were asked to indicate via button press whether the presented syllable-pairs were identical or not. Discrimination accuracy for original items was nearly perfect with no significant group difference. However, when participants had to decide solely on the basis of the vowels' durational cues (manipulated condition) discrimination performance of dyslexics was significantly inferior compared to controls. Hemodynamic brain activation during the original condition demonstrated activation of the bilateral auditory cortex with no significant group difference. Functional analysis of manipulated stimuli revealed an additional bilateral brain activation of the insular cortex in both groups. Moreover, during this condition controls demonstrated a significant activation within the left inferior frontal gyrus (IFG). In parallel to the dyslexics' inferior discrimination performance subtraction analyses exhibited decreased hemodynamic

activation of the insular cortices and the left IFG within dyslexics compared to controls. Our behavioural findings support the notion of an association of impaired temporal auditory processing and developmental dyslexia. Furthermore, our fMRI results indicate that the IFG and the insular cortex are at least part of a neural network involved in temporal auditory processing and which can be impaired in developmental dyslexia.

77. Morphological effects in the absence of semantic effects: a masked priming ERP study on French verbs. P. Royle (1)(2)(3), K. Steinhauer (3)(4), J. E. Drury (3)(4), and N. Bourguignon (1)(3). (1) Université de Montréal, Montréal, Canada (2) Centre hospitalier universitaire Ste-Justine, Montréal, Canada (3) Centre for Research on Language, Mind and Brain, Montréal, Canada (4) McGill University, Montréal, Canada.

Objective Morphological aspects of human language processing have been suggested to be reducible to the combination of formal (phonological or orthographic) and semantic effects (e.g., Bates & Godham, 1997). The question of semantic vs. morphological vs. formal processing can be investigated using evoked response potentials (ERPs) conjointly with priming paradigms, as shared representations between prime and target are assumed to facilitate lexical access (Forster, 1998). Unlike previous ERPs studies on morphological priming (Münte et al., 1999; Rodriguez-Fornells et al., 2002) we directly compared morphological to both semantic and formal priming (here shared letters) on verb targets, while using masked priming to reduce strategic effects related to prime perception (Forster, 1998; Holcomb & Grainger, 2006; Domínguez et al., 2008; Morris et al., 2008). Methods. Participants. Twenty healthy adults between 18 and 35 years of age participated in the experiment. All participants were right-handed native speakers of French and had (corrected to) normal vision. Stimuli Stimuli lists were developed to verify processing of inflected French verbs. For each target, three primes and their controls (matched in length and frequency) were used: Morphological: cassait – CASSE 'broke – break'; Formal: cassis – CASSE 'blackcurrant – break'; and Semantic: brise – CASSE 'break – break'. Word lists comprised 50% real-word target pairs. Of the real words, 50% were related pairs (semantic, formal or morphological), 50% controls-target pairs for task conditions. Filler real-word pairs made up the rest of the stimuli. All subjects saw all targets in two of the three priming conditions (and their controls). Procedure Participants followed a lexical decision procedure pushing a YES key for a real word and a NO key for a non-word. Winking periods were interleaved between the presentation of stimuli to reduce data loss from movement artifacts. Stimulus presentation is presented in Figure 1. Data recording and analysis EEGs were recorded continuously from 19 standard electrodes and were analyzed as event-related potentials (ERPs) time-locked to the prime. Representative consecutive time-windows between 0-1000 ms were analyzed with mean amplitude as the dependent measure. Behavioral reaction time data from the lexical decision was also recorded and analyzed. Results. There were no significant behavioral or ERP semantic priming effects. However, both morphological and formal priming effects were observed. These two last types of priming resulted in relative positivities. The absence of semantic priming cannot be attributed to subject effects, as a number of participants showed semantic priming in an unmasked priming task (Author et al., 2008). Conclusions. This pattern, in particular the presence of morphological priming in the absence of semantic priming, cannot be reconciled with models that attempt to reduce morphological aspects of language processing to a combination of semantics and orthography, but rather, agree with proposals viewing morphological processing as rapid, automatic and obligatory (e.g., Longtin et al., 2003; Morris et al., 2007). Our data are consistent with evidence from a large body of work in psycholinguistics and a growing body of neurolinguistic data showing evidence for abstract knowledge of morphological organization in the lexicon (McQueen & Cutler, 1998; Domínguez et al., 2004).

78. Cerebral convergence of sentence processing in speech and reading: Effects of differences in reading skill. D. Shankweiler (1,2) D. Braze (1) W. E. Mencl (1) W. Tabor (1,2) K. Pugh (1,3) R. K. Fulbright (3). (1) Haskins Laboratories, New Haven, CT, US (2) University of Connecticut, Storrs (3) Yale University, New Haven, CT, US.

Objective: The ability to glean similar information from spoken and written forms of a message is an essential characteristic of the language brain in literate societies, yet only in recent years has the neural architecture of the supramodal language system been an object of study in its own right. How are plastic connections within the language network modulated by reader skill differences? fMRI was used to investigate the impact of literacy skills in young adults on the distribution of cerebral activity during comprehension of sentence material in spoken and printed form. The aim was to discover where the supramodal language system is located and how it responds to comprehension challenges and differences in reading skill. Method: To probe these questions we examined BOLD activity in 36 readers representing a wide range of skill levels while they performed a semantic categorization task with matched written or spoken sentences that were either well formed or contained anomalies of syntactic form or pragmatic content. On whole brain scans, both anomalies increased net activity over nonanomalous baseline sentences, chiefly at left frontal and temporal regions. The anomaly sensitive sites correspond approximately to those that previous studies (Constable et al., 2004; Michael et al., 2001) have found to be sensitive to other differences in sentence complexity (object relative minus subject relative). We asked how sites of speech-print convergence are distributed with respect to heteromodal and unimodal cortical regions. Then we asked whether there is an effect of reading skill at some or all convergent regions. To obtain a quantitative measure of convergence on an individual subject basis, we computed a Convergence Index for each participant (the proportion of cortical cells within each anatomically-defined region of interest that responded to the anomaly contrast in both modalities). To discover whether convergence and reading skill are related we determined the correlation between the Convergence Index at each region and measures of reading comprehension. Results: Highest values of the Convergence Index were found at inferior frontal regions. The scatter plot (see figure) shows that values

of the Convergence Index at the dorsal portion of IFG are positively correlated, $r = .7$, with skill in reading comprehension. Other measures of skill (e.g., word reading) show a similar correlation. The left inferior frontal region is the principal site of speech-print integration and a major focus of reading skill differences. Conclusions: Most important, these findings lend neurobiological substance to the idea that reading skill can be interpreted as the graded convergence and unification of print representations with those of spoken language. A well-integrated supramodal language brain is a property of skilled readers but not unskilled. The findings also yield new evidence of the role of the inferior frontal region in binding speech and print into an integrated, supramodal system of representation.

79. Reading direction influences the perception of emotional and neutral words. R. Heath (1), L. El Ghaoui (2), L. El Shar (1), and R. Nsouli (1). (1) American University of Beirut, Beirut, Lebanon.

Findings for the lateralization of the perception of emotional words have been inconclusive. A frequent explanation for the mixed results has been the masking of higher order processing in the early stages of lexical processing by the robust right visual field/left hemisphere (RVF/LH) advantage for processing lexical data. The objective of the current study was to delineate the influence of reading direction in the perception of emotional and neutral words and thereby illuminate underlying mechanisms involved in the early stage of emotional word processing. First, we hypothesized that a group of solely Roman script readers (RO) would perceive words more accurately, regardless of valence, when the words were presented in the LVF. Conversely, a group of biliterate Roman/Arabic script readers (BI) would perceive words more accurately when presented in the RVF. Second, we hypothesized that the initial fixation position for the eye for RO participants would be at the beginning of an English word, whereas the initial fixation position for the BI group would be at the end of an English word, which corresponds to the beginning of an Arabic word. The perception test was an 18-item visual half field task with positive, negative, and neutral English words balanced across the visual fields. A target word was flashed briefly followed by four words, the target and three distracters. One distracter began the same as the target, one ended the same, and one neither began nor ended the same. The participants selected which word they thought they saw. Thirty-three RO participants and 44 BI participants completed the task. A letter cancellation task was also included. The RVF/LH superiority for the perception of words was statistically significant. Both script groups more accurately perceived positive words when the words were presented in the RVF whereas neutral words were perceived equally well in either visual field, which showed the lateralization of the perception of emotional words. The influence of reading direction was demonstrated by statistically significant interactions of visual field and script group. Also, the RO group was significantly more likely to choose the distracter that began the same as the target if the target appeared in the LVF and the BI group was more likely to choose a distracter that ended the same as the target word if the target appeared in the RVF. The results of the letter cancellation task confirmed that the RO group was more attentive to the LVF. In conclusion, the use of opposing reading directions in an emotional word perception task clarified the results. The script group and visual field interactions provided additional support for lateralization of the perception of emotional words at the early stage of lexical processing.

80. Functional neuroanatomical co-localization for reading and spelling: An fMRI study. J. Purcell (1), E. Napoliello (1), and G. Eden (1). (1) Center for the Study of Learning, Georgetown Univ., Washington, DC, US.

Neuroimaging studies of reading have identified involvement of left hemisphere inferior frontal (BA 44/45), temporoparietal (BA 40/39) and fusiform (BA 37) cortices (Pugh, et al. 2000). Although less frequently studied, these regions may also be involved in spelling (Beeson, et al. 2003). Left BA 37 is known to play a key role in orthographic lexical representations and, if found to be utilized for both reading and spelling, it would suggest that this region may contribute orthographic representations to both input and output processes of written language. Few studies have directly examined whether reading and spelling rely on the same neural substrates, and those that have, employed tasks involving word-spelling knowledge (Booth, et al. 2002; Rapp, et al. 2006) (e.g. imagine a word's spelling) as opposed to explicit spelling (e.g. write a word). This begs the question of whether overlapping neural activation would be observed across explicit reading and spelling paradigms. Here we studied 6 right-handed, monolingual subjects with typical reading/spelling levels to test the hypothesis that there would be common activation for reading and spelling, particularly in left BA 37. We employed a novel technique by having subjects touch type single words without visual feedback on an fMRI compatible QWERTY keyboard. Task-related activity associated with spelling was identified by contrasting typing of a spoken word with a motor task (altering key presses in response to an auditory cue). Subjects also performed a silent single word reading task (Cohen, et al. 2002) that was contrasted to attending to checkerboards. A random effects group analysis ($p < 0.05$, cluster-level corrected) revealed reading-related activity in left inferior frontal (BA 44, 45), middle frontal (BA 10), and fusiform (BA 37) gyri and bilateral cerebellum. For spelling we observed significant increases in left inferior frontal (BA 44, 45) and inferior temporal (BA 37) gyri, and right cerebellum, consistent with previous studies of written spelling or word spelling knowledge. A conjunction analysis of activation associated with reading and spelling ($p < 0.05$, cluster-level corrected) produced significant clusters in left inferior frontal (BA 45) and inferior temporal (BA 37) gyri, providing strong support for a role of these regions in both reading and spelling. Left BA 45 may not only facilitate decoding of written words from visual input, but also facilitate recoding of written words from semantic/phonological representations into their written form. Left BA 37 appears to be functionally relevant to both input level orthographic processing while reading, and also spelling of words during typing. Supported by NSF (SBE 0541953)

81. Enhanced activity in early visual word recognition for letter-rotation and pseudowords. A. Kim (1). (1) University of Colorado at Boulder, Boulder, US.

Recent neuro-imaging studies suggest that visual cortex activity is modulated by “high-level” variables during visual word recognition, including word frequency and orthographic regularity (e.g., Hauk et al., 2008). While it is not surprising that reading recruits visual cortex, the possibility that sensory cortex subserves high-level aspects of word processing, as opposed to low-level perceptual functions, is challenging to standard views of the relationship between perceptual and linguistic processing. We report event-related potential (ERP) studies examining the functional contribution of visual cortex to word recognition. Several studies report that visually presented words (and also faces) enhance the first prominent negative-going ERP component, concentrated over occipito-temporal scalp-positions (N170), more so than other visual objects (e.g., houses). This stimulus-specific N170 enhancement is consistent with functional specificity for words and faces, as are two further patterns. First, word N170 tends to be larger at left than right-hemisphere scalp positions, while face N170 tends to be larger in the right hemisphere. Second, some studies report delayed and enhanced N170 to inverted faces relative to upright faces but not to other inverted objects (e.g., houses; Rossion et al., 2003). Delay and enhancement of N170 by stimulus inversion may reflect functional specialization, but further investigation is needed to clarify the specific functional architecture underlying this pattern. We consider two different hypotheses about why stimulus scrambling (of which inversion is an example) enhances the N170 for visual words 1) greater recruitment of cortical systems that are specialized for processing visual word forms or 2) recruitment of attentional systems. In the current studies, we recorded ERPs elicited by words and word-like pseudowords that were either upright or “letter-rotated”. Letter rotation was intended to scramble the visual input in a manner comparable to whole-word inversion, without totally disrupting linguistic processing (one can still recognize the letters and their combinations). Subjects saw 120 stimuli in each of four conditions created by crossing the following variables: Word/Pseudoword and Upright/Rotated. All stimuli elicited a clear N170 component concentrated over occipito-temporal electrodes. Upright stimuli elicited strongly left-lateralized N170s. Letter-Rotated stimuli delayed and enhanced the N170 relative to upright stimuli, replicating Rossion et al (2001), and were strongly right-lateralized. We also examined the impact of stimulus and task experience by analyzing effects at early and late parts of the experimental session. Over the course of the session, upright stimulus N170s became more strongly left-lateralized, and rotated-letter stimulus N170s became less right-lateralized. No clear impact of the word/pseudoword variable was observed in the N170 time window. Enhancement and delay of N170 by letter rotation resembles previous effects of stimulus inversion, which have been interpreted as reflecting stimulus class specificity. We suggest that the right-lateralized impact of letter-rotation reflects recruitment of attentional mechanisms in response to the challenge of recognizing words under such conditions. The strong left-lateralization of word-elicited N170 suggests that left, not right, hemisphere areas are specialized for word recognition. This inference is also consistent with increasingly left-lateralized waveforms for both upright and letter-rotated stimuli over time within session. We will discuss these findings as well as related results involving orthographic regularity and semantic factors.

82. Written Language Impairments in Progressive Aphasia: A Reflection of Damage to Core Semantic and Phonological Processes. M.L. Henry (1), P.M. Beeson (2), S.Z. Rapcsak (3). (1) University of Arizona Department of Speech, Language, and Hearing Sciences, Tucson, US (2) University of Arizona Departments of Neurology and Speech, Language, and Hearing Sciences, Tucson, US (3) University of Arizona Department of Neurology and Southern Arizona VA Medical Center, Tucson, US.

Objective Acquired impairments of reading (dyslexia) and spelling (dysgraphia) result from damage to left-hemisphere cortical regions typically caused by stroke or neurodegenerative disease. Individuals may demonstrate poor irregular word reading/spelling (surface dyslexia/dysgraphia) or impaired nonword reading/spelling (phonological dyslexia/dysgraphia). Cognitive models of language suggest that these syndromes result from damage to specific processing components; however, theories vary with regard to the precise nature of the underlying functional impairment. According to dual-route models, these disorders result from the breakdown of lexical or sub-lexical procedures involved in reading and spelling (Coltheart, Rastle, Perry, Langdon & Ziegler, 2001). By contrast, connectionist models (e.g., Plaut, McClelland, Seidenberg & Patterson, 1996) propose that surface and phonological dyslexia/dysgraphia result from damage to central semantic and phonological representations that also support speech production/comprehension (Patterson & Lambon Ralph, 1999). The objective of the current study was to determine whether spoken language measures are predictive of written language performance in individuals with progressive aphasia (PA), as predicted by connectionist models, and to examine whether these language behaviors are supported by common neural substrates. **Methods** Fifteen individuals with PA and 15 healthy controls were administered a language battery including assessments of semantic knowledge (e.g., picture naming, auditory synonym judgment, spoken word-picture matching) and phonological skills (e.g., rhyme judgment, phoneme segmentation, phoneme blending), from which composite measures were derived. Written language was assessed using oral reading and writing-to-dictation of 40 regular words, 40 irregular words, and 20 nonwords. Voxel-based morphometry was used to identify cortical atrophy in a subset of patients (n = 11) relative to controls and to examine correlations between gray matter volume and selected language measures. **Results** Multiple regression analyses revealed that the combination of phonological and semantic composites scores accounted for a significant proportion of the variance (71-83%) in written language performance. The amount of unique variance explained by semantic versus phonological predictors varied along a continuum relative to stimulus type, with nonword reading/spelling predicted exclusively by phonological composite scores and low-frequency irregular (LF-irregular) word performance predicted largely by semantic composite scores (with a smaller contribution by the

phonological composite). Regional gray matter volumes were correlated with performance on semantic versus phonological tasks and with reading/spelling accuracy for LF-irregular words versus nonwords. Left perisylvian volumes significantly correlated with the phonological composite and with both nonword and LF-irregular word performance, whereas left temporal lobe volumes correlated with semantic composite scores and LF-irregular word performance. In an effort to isolate lexical-semantic aspects of processing, phonological composite scores were included as a covariate in the LF-irregular word regression, revealing significant correlations with temporal lobe volumes only. Conclusion Our findings indicate that spoken language performance is predictive of written language profile in individuals with PA and suggest that distinct left hemisphere cortical regions subserve semantic versus phonological processes regardless of language task/modality. These results are in accord with connectionist language models, which suggest that written language impairments arise from damage to semantic and phonological representations involved in spoken language. Future research should address visual/orthographic variables as additional contributors to written language performance. References Coltheart, M., Rastle, K., Perry, C., Langdon, R., & Ziegler, J. (2001). The DRC model: A model of visual word recognition and reading aloud. *Psychological Review*, 108, 204–258. Patterson, K., & Lambon Ralph, M. A. (1999). Selective disorders of reading? *Current Opinion in Neurobiology*, 9(2), 235-239. Plaut, D. C., McClelland, J. L., Seidenberg, M. S., & Patterson, K. (1996). Understanding normal and impaired word reading: Computational principles in quasi-regular domains. *Psychological Review*, 103(1), 56-115.

83. Unconsciously deciphering your doctor's handwriting: Subliminal invariance for handwritten words in the visual word form area. E.Qiao (1,2,3,4), F. Vinckier (1,2,3,4), M. Szwed (1,3,4), L. Naccache (2,3,4,6,7), R. Valabrègue 5, S. Dehaene (1,3,4), L. Cohen (2,3,4,6,7). (1) INSERM, Cognitive Neuro-imaging Unit, IFR 49, Gif sur Yvette, France (2) Université Paris VI, Faculté de Médecine Pitié-Salpêtrière, IFR 70, Paris, France (3) CEA, NeuroSpin center, IFR 49, Gif sur Yvette, France (4) Collège de France, Paris, France (5) CENIR, Université Paris VI, Faculté de Médecine Pitié-Salpêtrière, Paris, France (6) AP-HP, Hôpital de la Salpêtrière, Department of Neurology, Paris, France (7) INSERM, CRICM, UMRS 975, Paris, France.

Expert readers exhibit a remarkable ability to recognize handwriting, in spite of enormous variability in character shape – a competence whose cerebral underpinnings are unknown. Subliminal priming, combined with neuroimaging, can reveal which brain areas automatically compute an invariant representation of visual stimuli. Here, we used behavioral and fMRI priming to study the areas involved in invariant handwritten word recognition. Compared to printed words, easily readable handwritten words caused additional activity in ventral occipito-temporal cortex, particularly in the right hemisphere, while difficult handwriting also mobilized an attentional parieto-frontal network. Remarkably, however, subliminal repetition effects were observed across printed and handwritten styles, whether easy or difficult to read, both behaviorally and in the activation of the left visual word form area (VWFA). These results indicate that the left inferotemporal VWFA possesses an unsuspected degree of fast and automatic visual invariance for handwritten words -- although surprisingly this invariance can be reflected both as repetition suppression and as repetition enhancement.

84. Hemispheric asymmetries in handwritten word recognition. A. Barnhart (1) and S. Goldinger (2). (1) Arizona State University, Tempe, US. (2) Arizona State University, Tempe, US.

Despite the amount of convergent evidence suggesting that the brain's right hemisphere (RH) may have capabilities that make it especially adept at recognizing handwritten words in strongly right-handed individuals, only one study has looked specifically at the topic (Hellige & Adamson, 2007), and its findings were equivocal as it employed only three-letter nonwords. Research has shown that the RH relies more heavily on top-down information for recognition of words (Lindell, 2006) than does the left hemisphere (LH). In addition, the RH seems to be equipped with a visual subsystem that allows it to deal more efficiently with novel word forms (Marsolek, 2004). In two lexical decision tasks using the traditional lateralized visual half-field presentation methodology, we examined whether the RH exhibits benefits in handwritten word recognition relative to the LH and whether these benefits may be due to differences in accessing top-down information. Experiment 1 studied word frequency effects for laterally-presented printed and cursive words. Although frequency effects have never been demonstrated to differ between the hemispheres, we predicted that this difference would appear for handwritten items, as we recently observed that frequency effects are magnified for handwritten words (Barnhart & Goldinger, submitted). Although we did not find the predicted three-way interaction of Visual Field X Script X Frequency, lexical decision response times did reveal a reliable Script X Visual Field interaction, wherein printed words were recognized 39 ms faster by the LH than the RH. Cursive items did not show this same decrement from LH to RH, and in fact there was a negligible benefit for cursive words in the RH (see figure). Thus, the RH does seem to be specially equipped to disambiguate noisy, handwritten text. In Experiment 2, we examined top-down contributions to lateralized recognition of handwritten and printed words in a primed lexical decision task utilizing target words that were either semantically related to the dominant or subordinate meaning of the prime or were unrelated. Priming studies have shown that the RH exhibits prolonged, diffuse activation of semantic neighborhoods, while the LH quickly narrows activation to only dominant neighbors. We also varied the stimulus onset asynchrony between the prime and target to illuminate differences in activation over time for neighborhoods in each hemisphere. We expected to observe magnified priming effects for related handwritten words presented following long SOAs in the RH regardless of meaning dominance. Analysis of response times did not reveal any systematic interactions between script and visual field, but error rates produced a marginal ($p = .07$) four-way interaction of Visual Field X Script X Relatedness X Dominance with the Relatedness by Dominance interaction being magnified for handwritten words in RH. Dominant, related cursive targets were recognized with higher accuracy in the RH than LH, while printed targets did not show this pattern. Taken together, our

findings validate the research of Hellige and Adamson (2007). The top-down contributions to word recognition elicited by using real lexical items highlighted the role that the RH plays in the disambiguation of handwritten words.

85. Independent versus common lexicon for reading and writing: implications from lesion data. V. Balasubramanian (1), H. Cohen (2), A. Barrett (3). (1) Seton Hall University, South Orange, US (2) Universite Paris Descartes-CNRS, Paris, France (3) Kessler Foundation Research Center, West Orange, US.

The 'common lexicon theory' (CLT) postulates that one single mental lexicon serves both reading and writing (Coltheart & Funnell, 1987., Rapcsak & Beeson, 2002), whereas the 'independent lexicon theory' (ILT) claims that the input orthographic lexicon for reading is separate from the output orthographic lexicon for writing (Rapp 2002., Rapp, Benzing, & Caramazza, 1997). These theories deserve to be investigated further because they rest on data from a few case studies that were inconclusive. The objectives of the current study were 1) to analyze the reading and writing performance of two aphasics (LK & CBH) and 2) to discuss the issue of 'common' versus 'independent' lexicon theories in the face of the data obtained from these aphasics. LK, a 45-year-old right-handed male school teacher with a stroke induced lesion in the left temporo-frontal and basal ganglia areas, and CBH, a 59-year-old female with a diagnosis of bilateral parietal lobe lesion, served as the subjects of the current study (see figures 1, & 1a). Both subjects were tested on clinical test batteries such as 1) Boston Diagnostic Aphasia Examination, 2) Boston Naming Test, 3) Reading Comprehension Battery for Aphasics, and 4) Discourse Comprehension Test. LK's language performance profile on these batteries revealed a moderate-severe Broca's aphasia. CBH's performance on the same tests revealed a mild-moderate anomic aphasia. LK and CBH were also tested on two major experimental tests that focused on oral reading and writing: 1) Psycholinguistic Assessment of Language Performance in Aphasia (PALPA, Kay, Lesser, & Coltheart, 1992), and 2) Subtests of Johns Hopkins University Dysgraphia Battery (JHADB). In LK's performance, both reading and writing were found to be influenced by factors such as grammatical class, imageability and word frequency, spelling regularity, non-word, and homophone (Figures 2 & 3). Although the similar patterns of response in LK's reading and writing could be construed as supportive evidence for the CLT, the discrepancy between the presence of semantic substitutions in reading and its absence in writing would warrant a cautious interpretation. CBH's performance on JHADB and PALPA sub-tests related to reading and writing demonstrated the presence of relatively isolated agraphia (Tables 1-3). Written picture naming was performed at 50% accuracy level, whereas oral picture naming was achieved at 92.5 % accuracy level. (PALPA 53). In addition, there were specific domains of spelling impairment in CBH's performance: 1) Word-length effect; 2) Grammatical class effect; 3) Imageability/Frequency effect; 4) Spelling regularity effect; 5) Non-word effect and; 6) Homophone effect. The CLT finds itself in an incompatible position with several reports on isolated agraphias (Luzzi & Piccirilli, 2003). The presence of relatively isolated agraphia in CBH seems to support the position of ILT. The cases reported here clearly suggest the need for cross-cultural investigation of the issues using case-series analysis.

86. What's in a word? Or how EEG can inform us about the time course of the processing of complex words. R. Lebib (1), A. Krott (1). (1) University of Birmingham, Birmingham, United Kingdom.

Many models of morphologically processing assume the decomposition of morphologically complex words into morphemes and subsequent semantic-syntactic integration of these constituents¹. The time-course of these processes, however, is not well studied. Electroencephalographic effects related to morphological processing are often reported around 400 ms after stimulus onset and have been assumed to reflect semantic-syntactic integration processes². Even less is known about the timing of morphological decomposition. In the present study we examined the time-course of morphological processes by focussing on prefixed English words. Using a lexical decision task, we compared event-related brain responses (ERPs) to correct words (e.g. superhuman) with those to morphologically (e.g. overhuman) and orthographically (e.g. stuperhuman) manipulated words as well as nonwords (e.g. dastleporist). Morphological manipulations concerned the substitution of a prefix with a semantically similar one (e.g. over for super), while orthographic manipulations concerned the replacement or addition of a letter within the prefix (e.g. t inserted into super > stuper). Effects caused by these manipulations can inform us about the chronological access of morpheme and full-form representations. Morphologically manipulated words (overhuman) match the representations of two morphemes, but not a full-form representation. Orthographically manipulated words (stuperhuman) match only onto representations of the word stem (human), not the affix (super). Finally, nonwords match neither morpheme nor full-form representations. Comparing neural responses to real words (superhuman) with those to manipulated words revealed that morphologically manipulated words (overhuman), but not nonwords (dastleporist) or orthographically manipulated words (stuperhuman), showed a widely distributed amplitude reduction of the P2 component around 170 ms after stimulus onset. Because this effect was only present for morphologically manipulated words, but not for nonwords or orthographically manipulated words, it is most likely caused by the failure to match morphemic constituents onto full-form representations rather than the general failure to match a full-form representation. We can therefore conclude that morphological decomposition and the recognition of constituent morphemes must have occurred before 170 ms. Furthermore, electrophysiological results revealed that both morphologically and orthographically manipulated words as well as nonwords elicited a larger N400 component compared to real words. This effect is commonly associated with a lack of lexicality and higher demand in semantic integration processes^{2,3}. Interestingly, this effect lasted much longer for morphologically manipulated words than for orthographically manipulated words or nonwords, suggesting a longer-lasting integration process of the two constituents into a meaningful whole. Compared to real words, nonwords were the only stimuli that could not be decomposed into morphemes at all, having the potential to reveal the lack of decomposition processes. However, nonwords

did not differ from real words until around 300 ms after stimulus onset. Therefore, the decomposition process itself does not seem to lead to visible ERP effects. To conclude, our results provide a chronological framework for models of morphological processing that assume morphological decomposition, the match of the constituents against full-form representations and semantic integration of the constituents.

Syntax

87. The representation of lexical-syntactic properties of verbs: The theoretical contribution of fMRI. E. Shetreet (1), D. Palti (1), N. Friedmann (1), and U. Hadar (1). (1) Tel Aviv University, Tel Aviv, Israel.

Introduction: The processing of lexical-syntactic information associated with verbs is crucial for sentence comprehension. Verbs differ with respect to the number of complements they require (e.g., the verb sneeze has no complements, whereas the verb punish has one complement) and the number of complementation options they allow (e.g., the verb want can be linked to a noun-phrase, a nonfinite clause, or a finite clause, Dan wanted flowers, Dan wanted to smell flowers, or Dan wanted that Ruth will give him flowers, respectively). Verbs also differ with respect to the possibility to omit their complements (e.g., John ate and John ate an apple are both grammatical, whereas only John punished the boy is grammatical, but *John punished is not). Different linguistic theories have been suggested for the representation of these optional-complement verbs. One type of theory contends that the lexical representation of these verbs includes two complementation options: one with a complement and one without it. Other theories suggest that only one option of complementation is represented in the lexicon – the option with a complement, and, in case of complement omission, the relevant thematic role is being saturated (lexically or syntactically). Methods: Three experiments investigated the cerebral location and pattern of activation of these types of information. Experiment 1 tested the effect of number of complements by comparing verbs that took zero, one, or two complements. Experiment 2 tested the number of complementation options by comparing verbs of one, two, and three options. Experiment 3 attempted to determine the way verbs with optional complements are represented and which linguistic theory is neurologically valid, on the basis of the areas identified in Experiments 1 and 2. Nineteen Hebrew speakers performed a semantic decision task on auditorily presented sentences. Results and conclusions: Parametric analysis revealed graded activations in the left-superior temporal gyrus and the left inferior frontal gyrus (Figure 1) in correlation with the number of complementation options the verb has. By contrast, the areas that correlated with the number of complements, the medial precuneus and the right cingulate, are not conventionally associated with language processing. This suggests that processing the number of options is more specifically linguistic than processing the number of complements. The activations of the verbs with an optional complement were similar to other verbs with only one option for complementation. Additionally, verbs with an omitted optional complement did not differ from verbs with no complements. Thus, we conclude that the lexical entry of verbs with optional complements includes only the representation of the full form, and that the omitted form is generated by a lexical saturation operation. The importance of this study is not merely in these novel findings, but also in its nontraditional usage of fMRI: the putative functions of the areas that we identified were used to constrain cognitive theory and derive evidence supporting a particular linguistic approach to the representation of verbs.

88. A New Paradigm to Uncover Regions Sensitive to the Constituent Structure of Sentences. C. Pallier (1), A-D Devauchelle (1), Y. Boureau (1), Stanislas Dehaene (1). (1) INSERM-CEA Cognitive Neuroimaging Unit, Gif-sur-Yvette, France.

Language is recursive. It allows the speaker of a language to combine basic elements to create meaningful expressions, and each output can in turn be nested into a more complex expression. The perceiver must parse the resulting string to recover the nested constituent structure. To explore how constituent structure is represented in the brain, we built upon the classical contrast between word lists and sentences, reasoning that a brain region that encodes linguistic trees should show an activation that increases monotonically with the amount of hierarchical structure in the input. A first group of participants were scanned with fMRI while processing sequentially presented series of 12 words; The size of the constituents that could be constructed out of these words was systematically manipulated. At the lowest level, 12 unrelated words were presented. We next showed six unrelated constituents of two words, four constituents of three words, etc, all the way up to a well-formed right-branching sentence with 12 words. A second group of participants had to process similar stimuli where the content-words had been replaced by pseudowords, yielding jabberwocky-like constituents. This allowed us to control for semantic or transition probability confounds. The results indicated that when constituents became bigger, activation increased in left hemispheric regions located in the temporo-parietal junction (TPJ), posterior and anterior superior temporal sulcus (pSTS and aSTS), temporal pole (TP), inferior frontal gyrus (IFG, pars orbitalis and triangularis) and putamen. In the delexicalized “jabberwocky” version of the experiment, the pSTS, left IFG and the putamen still varied monotonically with constituent size, while the TP and TPJ responses were abolished (see Figure). Interestingly, these two regions tended to respond only to the 6- and 12-word constituents, when full meaningful sentences were frequently present. As an additional control condition for transition probability, the experiment also included series of 3 or 4 words extracted from sentences but that did not form sentence constituents. These sequences produced activations similar to those evoked by constituents of smaller size, consistent with the notion that genuine constituents, rather than any chunks of plausible consecutive words, drive the activation of the language network. Inspection of the shape of the hemodynamic response revealed that responses were not just amplified, but also delayed, when the stimulus afforded the construction of larger constituents. These results can be accounted for by

simple model of neural responses, which supposes that neurons firing to each of the current constituent's words maintain a sustained level of activity until the end of the constituent is reached. In summary, our experiments pinpoint a novel feature of language networks – their monotonic response to the size of sentence constituents. Furthermore, we evidence a dissociation between putamen/pSTS/IFG regions, which respond whenever syntactic constituents are present, and TP/aSTS/TPJ regions, which seem to require the presence of additional lexico-semantic information. The latter regions either integrate incoming words into semantic constituents, or rely on word-based syntactic information (e.g. subcategorization frames) to build constituents.

89. Sensitivity to syntax in visual cortex: the role of form typicality. *S. Dikker (1), H. Rabagliati (1), T.A. Farmer (2), and L. Pylkkänen (1). (1) New York University, New York, US. (2) Sackler Institute for Developmental Psychology, New York, US.*

Introduction Several studies have shown that syntactic factors can affect brain responses as early as 130ms (e.g., ELAN; Friederici/TICS2002). However, the mechanisms that allow this rapid extraction of syntactically relevant information remain largely unexplored. This issue was recently addressed in a series of MEG experiments which found that syntactic violations elicit increased amplitudes in the visual M100 component, generated in visual cortex at ~120ms (Dikker et al., Cogn2009). This is surprising, since no M100 sensitivity to linguistic factors has been previously reported for words in isolation. Therefore, the most likely interpretation of these results is that continuous syntactic predictions are generated based on context, including estimates about the likely physical appearance of an upcoming word category. What might these estimates consist of? Dikker et al. only found M100 effects when unexpected words contained a closed-class category-marking morpheme (CCM), like –ed in report-ed. This suggested CCMs may play a special role in checking category predictions during visual analysis. However, although CCMs are undoubtedly indicative of word category, so are many other perceptual features. For example, (phonological) form features of words tend to cluster within categories: e.g., certain feature combinations occur relatively more often in nouns than in verbs, and are therefore more 'typical' (indicative) of the noun category (Farmer et al., PNAS2006). Generally, words containing CCMs are highly typical of their category. Here we tested whether form typicality is sufficient for an M100 effect of syntactic expectedness or whether the presence of CCMs is necessary. **Method/Design** Using word-by-word reading in MEG, we tested three types of nouns in both unexpected and expected contexts: (i) bimorphemic nouns with a CCM (e.g., farm-er), (ii) 'typical' nouns; and (iii) 'neutral' nouns. See Fig1 for examples. In sentences with an adjective (beautiful) the expectation for a noun was met. Sentences with an adverb (beautifully) violated the expectation for a participle (like dressed). Bimorphemic and typical nouns share significantly more form features with nouns than with participles, whereas neutral nouns share features with both. Thus, if the M100 is sensitive to form estimates (and not CCMs exclusively), an effect of context on M100 amplitude should be obtained for bimorphemic and typical nouns, but not neutral nouns. **Analysis/results** (a) Dipole analysis of the M100 peak, consistently localizing in visual cortex, revealed an effect of context for both typical and bimorphemic nouns, showing that CCMs are not crucial for the early detection of word category violations. No such effect was found for the neutral nouns (Fig1). (b) A mixed effects regression analysis on individual trials' M100 peak amplitude showed that words whose form was less consistent with the predicted word category (nouns in the expected context; participles in the unexpected context) generated an increasingly larger M100. This suggests that the M100 is sensitive to the extent to which form predictions are satisfied. **Conclusion:** These findings suggest that visual cortex is sensitive to probabilistic form-estimates based on prior syntactic information. We believe this result contributes an important piece to the puzzle how language processing can be executed rapidly and efficiently.

90. Adapting to complexity: fMRI adaptation distinguishes syntactic specificity in subregions of Broca's Area. *A. Santi (1), and Y. Grodzinsky (2). (1) McGill University, Montreal, Canada. (1) Max Planck Institute for Human Cognition and Brain Sciences, Leipzig, Germany. (2) McGill University, Montreal, Canada.*

We know Broca's area demonstrates greater activation for noncanonical (1, 3) than canonical (2, 4) sentences, but is this due to a general complexity contrast or a more specific one? The current fMRI adaptation study sought to distinguish between general and selective syntactic accounts of Broca's area by comparing two complexity factors: canonicity (ie, subject vs object extraction) and relative clause position (ie, right-branching (3, 4) vs center-embedding (1, 2)). According to global syntactic accounts, Broca's area is responsible for computing all syntactic representations, but is recruited more the greater the syntactic complexity (Caplan et al., 2000; Just et al., 1996; Stromswold et al., 1996; Friederici, 2006). General syntactic accounts of Broca's area contrast with ones that stipulate it is sensitive to a selective dimension of syntactic complexity represented by the canonicity contrast (Bornkessel et al., 2005; Grewe et al., 2005, 2006; Grodzinsky, 2000; Santi & Grodzinsky, 2007b). In this experiment we investigated adaptation to the two complexity factors – canonicity and relative clause position - in a fast-event related design with 18 participants. A deconvolution analysis demonstrated that posterior Broca's area (BA 44) adapted to both canonicity and relative clause position, whereas anterior Broca's area (BA 45) adapted to canonicity only. Therefore, the results suggest a parcellation of Broca's area with it being general to syntax posteriorly and selective to syntax anteriorly. Furthermore, the left superior temporal gyrus (STG) and right inferior precentral sulcus (IPS) adapted to both complexity factors. These results implicate multiple regions to be engaged, generally, during syntactic comprehension, though their functions may generalize beyond syntax. The finding that anterior Broca's area is selective to the canonicity contrast requires further inquiry to better understand the fundamental element of selectivity. Some suggested avenues to be pursued are discussed. 1. The boy [who the tall girl is smiling at _] is Derek 2. The boy [who _ is smiling at the tall girl] is Derek 3.

Derek is the boy [who the tall girl is smiling at _] 4. Derek is the boy [who _ is smiling at the tall girl]

91. Verb Bias in Mandarin Relative Clauses. Y. Lin (1), S. Garnsey (1). (1) University of Illinois, Urbana-Champaign, Champaign, US.

Relative clauses processing has attracted the attention of psycholinguists for many decades. While some researchers are interested in processing theories, others are interested in comparing relative clauses with other syntactic structures. The fact that Mandarin relative clauses are head-final offers us ways to investigate sentence comprehension in Mandarin. Since the head of the relative clause comes at the end of the structure, it is therefore not until people come to the relative marker “DE” or the relative clause verb that make them realize they were led down the garden path. Due to the identical structures between an SVO structure (1) and an object relative clause (2), we can examine people’s reaction when they find out they misanalyze the sentence. (1) SVO [老師 討厭 那個 家長]。 Teacher dislike that parent (The teacher dislikes that parent.) (2) Object relative clause [老師 討厭 那個 家長] 痛罵 的 學生。 Teacher dislike that parent scold DE student (The teacher dislikes that student who the parent scolded.) Sentences (1) and (2) are entirely identical until “scold”. This relative clause verb in (2) makes people realize that (2) is not a simple SVO sentence. We predict that people tend to slow down at this region once they find out this is not a canonical structure. The result of the first manipulation confirmed our hypothesis. Subjects’ reaction times were identical across two sentence types until “parent”. However, reaction times went up at “scold”, indicating that people were surprised to find out their initial analysis was incorrect. Even though we know people tend to interpret the initial NVN in (2) as simple SVO structure, we are interested in seeing whether people’s initial analysis would be affected by other factors such as verb bias. In the following experiment, we replace the direct-object (DO) verb such as “dislike” in (2) with a sentential complement (SC) verb such as “claim” in (3). (3) 老師 宣稱 那個 家長 痛罵 的 學生 成績 進步。 Teacher claim that parent scold DE student grade improve (The teacher claimed that the student who the parent scolded has improved in his grades.) Since “claim” is an SC verb, it requires a clause to follow, making the following noun “that parent” as the subject of the following clause. We thus predict that people’s reaction time at “scold” in (3) will not be as lengthened as the “scold” in (2) since they would be expecting a verb coming up later in the sentence. The results of our experiment confirmed our hypothesis again. When we compared the reaction time for “scold” in (2) and (3), we found that people did not slow down in (3) as much as in (2), indicating that they were using the verb bias effect to disambiguate sentences. Our results confirmed that sentence comprehension is incremental and people are capable of using different cues such as verb bias during sentence comprehension.

92. The early left anterior negativity (ELAN): A reliable marker of phrase structure violations, or a context-driven artifact? E. Pauker (1), K. Steinhauer (1). (1) McGill University, Montreal, Canada; Centre for Research on Language, Mind and Brain (CRLMB), Montreal, Canada.

A considerable number of influential studies using a phrase structure (PS) violation paradigm in spoken German (and Italian) sentences have consistently reported early left anterior negativities (ELANs) between 100 and 300 ms (Hahne & Friederici, 1999, Friederici, 2002, Rossi et al., 2006). The ELAN’s short onset latency was taken as an important marker of very early automatic parsing processes and has been contrasted with subsequent morpho-syntactic parsing stages reflected by later LANs (300-500 ms). More recent research has cast doubt on this interpretation and discussed alternative accounts for the ELAN, including baseline problems due to systematic lexical and prosodic differences between violation and control conditions (Hagoort et al., 2003; Steinhauer & Connolly, 2008). The long duration of some ELAN effects (e.g., more than 1400 ms in Rossi et al., 2006) also seems incompatible with an early automatic process. To better understand the etiology and functional significance of ELAN- and LAN-like ERP components, we created a novel, fully balanced PS violation paradigm in English avoiding previous confounds: Averages across (i) violation conditions (C+D) and (ii) control conditions (A+B) share identical baselines and identical target words. A The man hoped to enjoy the meal with friends. B The man cooked the meal to enjoy with friends. C The man hoped to *meal the enjoy with friends. D The man cooked the *enjoy to meal with friends. (Note: * indicates the PS violation; target words are underlined.) A previous reading study using these sentences found LAN-like negativities after 300 ms and subsequent P600s, but no ELANs (Steinhauer et al., 2006). Methods. Here we replicated the study with 40 spoken sentences per condition, in both young (n=20) and older adults (65-85 years; n=12). EEG was recorded continuously from 19 electrodes (10-20 system, SynAmps2 DC, 500 Hz/24 bit sampling), and data were analyzed using EEProbe software. Results. In young adults, PS violations elicited a biphasic pattern consisting of a right-lateralized negativity (400-750 ms) followed by a P600-like positivity (750-1700 ms), as well as a sustained left-frontal negativity after 300 ms (Figure 1). A somewhat earlier and more frontal negativity for PS violations was observed in comparisons of conditions A and D that are similar to the German PS violation paradigm previously found to elicit ELANs (Hahne & Friederici, 1999). However, although the target verb was kept constant in this contrast, these conditions still differed in terms of prior context. In fact, contrasting B and C results in the inverse pattern, suggesting a context rather than a violation effect. Older subjects generally elicited reliable P600 components but reduced negativities. Discussion. The present study adds important new data to advance our understanding of ERP correlates for PS violations. First, early ELAN-like components may be partly due to contextual differences between violation and control conditions rather than the violation per se. Second, negativities preceding the P600 in PS violations seem to vary in scalp distribution and are affected by age. Third, sustained frontal negativities appear to be independent of early LAN-like effects and may reflect working memory load.

93. P600 and N400 effects during language comprehension reflect dissociation of structural and semantic processing difficulty. A. Kim (1) | Pytkannen (2) L. Osterhout (2). (1) University of Colorado at Boulder, Boulder, US. (2) University of Washington, Seattle, US.

ERP studies of language processing often report that grammatically anomalous words elicit a slow, centro-parietal positive wave (P600). This is typically associated with grammatical processing and distinguished from N400 enhancement associated with semantic processing difficulty. However, some studies report P600-like effects for misspelled words (Munte, Heinze, Matzke, & Wieringa, 1998; Vissers, Kolk, & Chwilla, 2005), calling into question grammar-specific functional interpretations of the P600. Vissers et al. argue that the P600 reflects a re-processing response, which occurs not only to grammatical anomalies but to a wider class of unexpected linguistic events. Here we replicated P600-like effects to misspellings in a new language, English. We also examined sentence-embedded pseudowords whose orthographic regularity was manipulated parametrically (e.g., “plark” > “whark” > “psark” > “dfark”). P600 amplitude increased, while N400 amplitude decreased, as pseudowords became increasingly structurally deviant. At the ends of the manipulation, word-like pseudowords elicited only enhanced N400 effects, and illegal pseudowords elicited only P600 effects. We account for this pattern of effects in terms of a tradeoff between structural processing difficulty (manifest in P600 effects) and semantic processing difficulty (manifest in N400) during language processing. Both types of processing are likely involved in multiple processing domains, within and beyond language. Furthermore, we argue that, while evidence is mounting that the eliciting conditions of P600 are quite general, functional accounts in terms of “unexpectedness” and related concepts are insufficient, because they fail to capture the dissociation between N400 and P600 in several language processing situations. References Munte, T. F., Heinze, H.-J., Matzke, M., Wieringa, B. M., and Johannes, S. (1998). Brain potentials and syntactic violations revisited: no evidence for specificity of the syntactic positive shift. *Neuropsychologia*, 36(3): 217–226. Vissers, C. T., Chwilla, D. J., and Kolk, H. H. (2006). Monitoring in language perception: The effect of misspellings of words in highly constrained sentences. *Brain Research*, 1106(1): 150–163.

94. An investigation of the neural generators of ERP indices of syntactic processing using proficiency-related ERP modulations in an ERP-fMRI paradigm. E. Pakulak (1), M. Dow (1), H. Neville (1). (1) University of Oregon, Eugene, US.

Event-related potential (ERP) studies of syntactic violations typically report a biphasic response in which an earlier negativity, often maximal over left anterior sites (LAN), is followed by a later positivity usually maximal over posterior sites (P600). Research concerning the neural generators of these components is comprised chiefly of fMRI studies which use the same stimulus materials previously shown to elicit these ERP effects, dipole modeling of data from magnetoencephalography (MEG), or ERP studies of patients with focalized brain lesions (e.g., Friederici et al., 2003; Friederici & Kotz, 2003; Friederici et al., 2000; Kotz et al., 2003). Results from these studies have implicated as possible neural generators of the LAN the frontal operculum, adjacent to inferior frontal gyrus (IFG), and anterior superior temporal gyrus (STG), and as possible neural generators of the P600 the basal ganglia and posterior STG. Here we take a novel approach to this question. Using an auditory syntactic violation paradigm, we recorded ERP and fMRI data from adult monolingual native speakers of English who varied on standardized measures of English proficiency. Individual differences in syntactic proficiency were associated with marked and significant differences in ERP responses to syntactic anomalies. We employed proficiency-related modulations of ERP indices of syntactic processing in specific regions and time windows to constrain the interpretation of fMRI activations to the violations. Specifically, we used proficiency-related modulations in the LAN and P600, quantified by average difference amplitude across different electrode sites and time windows, as covariates in the analysis of fMRI data from the same participants. Results suggest that multiple neural generators may contribute to both effects. The left IFG was implicated in the generation of the anterior negativity, even when this effect was extended temporally and present over right hemisphere sites. Additional activations specific to modulations in an early time window over left anterior sites was also observed in left temporal pole. Several posterior temporal and temporoparietal areas, including left posterior middle temporal gyrus, supramarginal gyrus, and angular gyrus, as well as the basal ganglia were implicated in the generation of the P600. These results fit a priori hypotheses based on previous findings, suggesting this is a potentially powerful approach. Additionally, they illustrate the potential for the use of individual modulations in ERP components in conjunction with fMRI to provide insight into the interplay between ERP and fMRI data and the neural generators of ERP indices of syntactic processing and language processing more generally.

95. Cortical Activations Related to Syntactic and Semantic Violations in Japanese: An fNIRS Study. S. Ayano (1), Y. Nishimura (1), K. Sugisaki (1), N. Hattori (1), Y. Inokuchi (1), S. Kojima (2), M. Komachi (3), Y. Nishimura (4), M. Ogawa (1), M. Okada (1), Y. Otsu (2), S. Umeda (2), T. Yamamoto (1), E. Yoshida (1). (1) Mie University, Tsu, Japan. (2) Keio University, Tokyo, Japan. (3) Shizuoka University, Shizuoka, Japan. (4) Suzuka University of Medical Science, Suzuka, Japan.

One of the fundamental assumptions in linguistic theory is that our knowledge of language has a modular nature, and that different modules are responsible for the structure and the meaning of a sentence. This study addresses the question of whether such modularity of linguistic knowledge is reflected in cortical activations related to sentence processing, by using near-infrared spectroscopy (NIRS) imaging. Japanese is a language that exhibits a heavy use of numeral quantifiers, which consist of a numeral and a classifier that matches with the type of object being counted. For example, in (1a), the noun ‘cat’ is accompanied by a classifier hiki that is used to count animals, while in (1b), the relevant noun is followed by a classifier dai that is used to count machines, leading to a ‘semantic’ violation. (1) a. Gakkou-no mae-ni neko-ga 3-hiki imasu. school-Gen front-at cat-Nom 3-Cl exist ‘There are three cats in front of the school.’ b. * Gakkou-no mae-ni neko-ga 3-dai imasu.

school-Gen front-at cat-Nom 3-CI exist Numeral quantifiers are also constrained by a structural restriction: A numeral quantifier cannot be associated with a noun within a Postpositional Phrase (PP), when the quantifier appears outside the PP (Miyagawa 1989). Thus, while a quantifier modifies a noun accompanied by a Case-marker in the grammatical example (2a), the quantifier 3-hon appears outside the PP and hence is unable to modify the noun 'tree' in the ungrammatical sentence (2b). (2) a. Ki-no ushiro-o kitune-ga 3-hiki hasitteimasu tree-Gen behind-Acc fox-Nom 3-CI running. 'Three foxes are running behind three trees.' b. *[PP Ki-no ushiro-o] 3-hon kitune-ga hasitteimasu tree-Gen behind-Acc 3-CI fox-Nom running. Linguistic theory argues that the constraint responsible for the ungrammaticality of (1b) and the one responsible for the ungrammaticality of (2b) belong to different knowledge modules: The former belongs to the 'semantic' module and the latter belongs to the 'syntactic' module. A recent study using ERP (Sakai et al. 2006) demonstrated that the violations as in (1) evoke N400, and argued for the view that the relevant ungrammaticality is 'semantic' in nature. In light of this finding, a new question arises as to whether the processing of sentences like (1) and that of sentences like (2) lead to different cortical activations. To address this question, we conducted a NIRS experiment. The subjects were 24 right-handed healthy adults, all of whom were native speakers of Japanese and from all of whom we obtained signed informed consent. The probes of the NIRS machine were placed on the subject's frontal and parietal areas, and changes in the oxygenated hemoglobin concentration (oxyHb) were measured during the presentation of sentences as in (1) and (2). Our results revealed that the processing of sentences in (1) and that of (2) in fact lead to distinct cortical activations: In (1), the oxyHb changes were observed in the right prefrontal cortex, while in (2), the oxyHb changes were observed in the left prefrontal cortex. These results are consistent with the view that our knowledge of language has a modular nature.

96. Phonological similarity and morphological identity: a lexical access ERP study in Brazilian Portuguese. A. Franca (1) M. Lemle (1) A. Gesualdi (2) M. Cagy (3) and A. Infantesi (1). (1) Federal University of Rio de Janeiro, Brazil (2) CEFET, Rio de Janeiro, Brazil (3) Federal Fluminense University, Niteroi, Brazil.

Granted that lexical items have internal syntax, what is the N400 related to? What factors can delay or hasten it? This is a crossmodal priming study of Brazilian Portuguese words (auditory prime - visual target), matched for frequency, assessed by reaction times (RTs) and event-related brain potentials (ERPs). Thirty-six college students were asked to press a button as to their lexical decision with respect to targets. The test comprised 360 prime-target pairs, 120 of which were the experimental ones: a phonological group (PG) of sixty pairs with similar onsets (batata-barata 'potato'-'cockroach') and a morphological group (MG) with 60 pairs holding a morphological relationship (puro-pureza 'pure'-'purity'). PG and MG were divided into three subgroups each (PG1, PG2, PG3; MG1, MG2, MG3) of 20 pairs with targets of increasing lengths: 5 to 6 phonemes in PG1; 7 to 8 in PG2, and 9 to 10 in PG3. Regardless of the variation in the number of phonemes, words in PG were formed by a root merged to one nominalizing morpheme. Contrastingly, words in MG had from one to three morphological layers: targets in MG1 had one layer and were 5 to 6 phonemes long, two layers in MG2 and 7 to 8 phonemes, and three layers and 9 to 10 phonemes in MG3. Additionally, there were 180 control pairs whose targets were non-words, 40 pairs in which prime and target were identical, and 20 pairs of synonymous fillers. The average number of overlapping phonemes in corresponding groups was controlled. If arbitrary meaning fares differently from compositional layers, our hypothesis is that globe is interpreted arbitrarily, but globalization contains additional morphological layers (globo, globalizado) that are interpreted compositionally one by one. In PG, a target such as samambaia 'fern' is similar in linear size to globalized, but has no layers. If lexical activation is detected at the point of arbitrary interpretation, then samambaia would yield a longer latency N400 than globalized. The EEG signal was recorded continuously and was digitized on-line with a sampling frequency of 400Hz in a 12-bit A/D resolution. ERPs were calculated for all subjects at each derivation. Wilcoxon test, was used to compare targets. Figure 1: Comparison between reaction times and ERP latencies for targets in both groups As it can be seen in Figure 1, PG1 targets yielded significantly faster RT (707ms) and cortical responses (572ms) than PG2 (751ms/595ms) and PG3 (847ms/644ms). Interestingly, differences in the number of phonemes and layers in the morphological groups did not result in different ERP latencies (MG1 568ms; MG2 563ms; and MG3 567ms). Moreover, the MG ERPs were significantly faster than those of the PG. Thus, rather than phonology, morphological relatedness between prime and target seems to be an acceleration factor for target activation in the brain assessed by N400. Nevertheless the behavioral findings of the MG (MG1 706ms; MG2 770ms; MG3 804ms) are very similar to those of PG. These findings point to the significant conclusion that while reaction times relate to the whole word, N400 ERPs detect the moment of arbitrary pairing of sound and meaning.

97. Neural correlates of syntactic processing in primary progressive aphasia. S. M. Wilson (1), J. M. Ogar (1), F. Agosta (1), B. L. Miller (1), N. F. Dronkers (2), M. L. Gorno-Tempini (1). (1) Memory and Aging Center, Department of Neurology, University of California, San Francisco, CA, US (2) Center for Aphasia and Related Disorders, Veterans Administration Northern California Health Care Service, Martinez, CA, US.

Primary progressive aphasia (PPA) is a clinical syndrome in which degeneration of dominant hemisphere language regions is associated with progressive speech and/or language deficits. In this study, we investigated the neural correlates of syntactic processing in two variants of PPA: progressive non-fluent aphasia (PNFA) and semantic dementia (SD). We used voxel-based morphometry (VBM) to identify which regions in the normal syntactic processing network are atrophic in these PPA variants, and functional magnetic resonance imaging (fMRI) to determine whether these regions or others show abnormal functional activity. Fourteen patients with PPA and 21 age-matched controls performed a sentence-picture matching task with seven conditions varying in degree of syntactic complexity. In normal controls, regions modulated by syntactic complexity included

the left inferior frontal gyrus (IFG), posterior superior temporal gyrus and sulcus (pSTG/S) and anterior superior temporal gyrus and sulcus (aSTG/S). PNFA patients showed atrophy in left perisylvian regions including the IFG, and were significantly impaired in syntactic comprehension, consistent with prior studies. Overall functional activity (task versus rest) was not reduced in any atrophic regions. However, modulation of the IFG and pSTG/S by syntactic complexity was absent in PNFA. This was not simply an effect of time on task, because reaction time was modulated by syntactic complexity equivalently in PNFA and in controls. PNFA patients also showed increased activity in more anterior left prefrontal regions, likely reflecting compensatory processes. In SD patients, there was extensive bilateral anterior temporal atrophy, but excellent syntactic comprehension, again consistent with previous studies. Temporal atrophy extended sufficiently dorsally and posteriorly to overlap both anterior and, to a lesser extent, posterior temporal sites that were modulated by syntactic complexity in the control group. Remarkably however, functional activity in these regions did not differ from controls, either in overall terms (task versus rest), or in modulation by complexity. In sum, these data suggest that both the IFG and superior temporal cortex play crucial roles in syntactic processing, since both regions showed abnormal functional activity in PNFA patients, who have syntactic deficits, and normal functional activity (despite significant atrophy) in SD patients, whose syntactic processing is spared.

98. Developmental Dyslexia: ERP correlates of anomalous morphosyntactic processing. C. Cantiani (1,2), M.L. Lorusso (2), P. Perego (2), M.T. Guasti (1). (1) University of Milano-Bicocca, Milano, Italy (2) Scientific Institute "E.Medea", Bosisio Parini (LC), Italy.

The linguistic nature of Developmental Dyslexia (DD) is still the object of an open debate, based on the frequently reported overlap with Specific Language Impairment (Bishop and Snowling, 2004). While phonological difficulties have been definitely demonstrated and semantic ones basically excluded, there is no agreement concerning morphosyntax, as limited evidence has been found suggesting dyslexics' difficulties in this domain. To better investigate these aspects of language, particularly sensitive measures should be used, such as event-related potentials (ERPs). According to recent neurocognitive models (Friederici, 2002), a biphasic electrophysiological pattern (LAN/P600) is normally expected in response to morphosyntactic violations, while a N400 component is expected in response to semantic violations. Differences in these electrophysiological patterns have been sporadically reported in Dyslexic participants (Rispen et al., 2006), even if linguistic difficulties did not emerge from standardized tests of language comprehension. In the present study, 168 sentences including subject-verb agreement violations were auditorily presented to 14 Italian speaking adults with DD without any history of language impairment (aged 20-28 years) and 14 unimpaired control participants matched on age and sex, while ERPs time-locked to the critical morpheme were recorded. Two variables were manipulated: Grammaticality (correct or incorrect) and Subject Number (singular or plural). Partially in line with expectations, agreement violations evoked in the control group a broad positive wave (P600) between 450-900 ms, but no Left Anterior Negativity. A similar pattern seems to emerge in the dyslexic group. However, statistical analysis of the mean amplitude in the characteristic time windows showed subtle differences between the two groups concerning the amplitude of the P600 component. Moreover, differently from control participants, dyslexics had a statistically significant early negativity (peaking around 300 msec) broadly diffused all over the scalp that cannot be functionally interpreted as a LAN (reflecting the detection of the morphosyntactic error), but rather as a N400 component (reflecting the involvement of semantic processing). A partially compensation for the syntactic deficit by using neural circuitry associated with semantic processing was also found in a previous study on children with language impairment (Fontaneau and van der Lely, 2008). Statistically significant results emerged from the number manipulation. While control participants showed similar electrophysiological responses for singular and plural sentences, dyslexic participants had a broad positivity in response to the plural grammatical sentences, partially obscuring the P600 in response to the ungrammatical counterparts. A possible explanation involves the complexity of the plural forms with respect to the singular ones: plural NPs are considered marked forms and tax the sentence processing mechanisms more than singular NPs (Kaan, 2002). These further cognitive demands might have stronger effects in dyslexic participants than in controls. On the whole, these results support the hypothesis of different language processing modalities in dyslexic participants. Further investigations concern the involvement of dyslexic participants with a concomitant language impairment, in which morphosyntactic difficulties are established by standardized tests and a grammaticality judgement task. Preliminary results on a little sample (N=10) showed an electrophysiological trend similar to pure dyslexic participants.

99. Complexity and Grammaticality, a view from agrammatism. N. Grillo (1). (1) Centro de Linguística da Universidade Nova de Lisboa, Lisbon, Portugal.

Lesion studies and imaging studies both have shown a critical involvement of Broca's area in the computation of non-local syntactic dependencies, i.e. movement involving inversion of the canonical Subject Verb Object order of arguments Noun Phrases (NPs) (e.g. The boy that the girl kissed t is tall) (see Grodzinsky 2000; Friederici 2006; Caplan 1999). These structures have also been shown to be more complex than subject relatives (SRs) (Gibson, 1998). We propose that a single underlying principle of economy of computation is responsible for the complexity effects associated with noncanonical sentences and the grammatical restriction on syntactic movement and that the same principle can explain the asymmetry between SR and OR in agrammatical aphasia. Contemporary linguistic theory has shown that while the length and depth of syntactic representation is virtually unbounded, core syntactic relations have to be built in a local domain. More specifically a local syntactic relation has to be built with the closest element capable of bearing that relation. Relativized Minimality (RM) (Rizzi 1990, 2004), states that a

local structural relation cannot hold between X and Y if Z is a potential bearer of the relevant relation and Z intervenes between X and Y. This principle is illustrated in (2). (1) X...Z...Y (2) a. When did you say that he arrived <when>? b. *When did you say who arrived <when>? Wh-movement of “when” in (2-b) is blocked by the intervention of another wh-element “who”. Similarly, a necessary requirement for the successful representation of object movement in ORs is the activation of the full set of morphosyntactic features associated with the object NP (the boy) so that it can be distinguished from the intervening subject (the girl). (3) Show me the boy that the girl kissed <the boy>; Activation of morphosyntactic features has a processing cost, and the total cost for representing a given NP will increase proportionally to any increment richness of the feature structure required for a given syntactic configuration to be grammatical. Incomplete activation of the feature structure might lead (in the case of ORs but not SRs) to the inability to distinguish between the object NP and the intervening subject, i.e. to a RM effect. This, together with the assumption that agrammatic aphasic’s syntactic processing capacity is reduced, predicts that these patients will do better with ORs than with their subject counterpart. In SRs, in fact, movement of the subject does not cross any potential intervener, therefore the overall complexity of these structures is predicted to be lower and no Minimality effects are expected to arise. This theory has similar implications for acquisition (see also Adani 2009 and Friedmann et al. 2008) and complexity effects observed in unimpaired adults. An advantage of the feature-based account, when compared to e.g. Gibson (1998), is that the degree of complexity can be modulated according to the structural similarity of the moving and intervening NPs as shown in Mak et al. (2002, 2006) Garraffa and Grillo (2008) with animacy distinctions in both unimpaired adults and agrammatics.

100. Neurophysiological Evidence for the Impact of Grammatical Voice on Verb Processing. M. Paczynski (1), G. Kuperberg (1,2). (1) Tufts University, Medford, US. (2) Massachusetts General Hospital, Boston, US.

INTRODUCTION: Our experiment investigated neural activation differences in processing active versus passive voice in simple English sentences. The passive voice assigns the Patient role (undergoer) of a transitive verb to the subject position, unlike the canonical active voice in which the grammatical subject is assigned the Agent role (actor). The non-canonical argument ordering in passives leads to processing difficulty, which sometimes results in the incorrect reversal of thematic role assignment (Ferreira, 2003). Here we investigate effects of voice on verb processing using event related potentials (ERPs). The passive related difficulty may be due to greater initial costs in computing the link between the subject noun phrase (NP) and the Patient role, leading to a P345 effect, or it may be due to a revision and reanalysis of syntactic deep-structure, leading to a P600 effect. Additionally, we tested whether inanimate subject NPs would be perceived as more Patient-like than animate subject NPs, as previously proposed (e.g. Trueswell, Tanenhaus & Garnsey, 1994), thereby facilitating the assignment of thematic roles in passive structures. METHODS: We chose 240 animate and inanimate nouns to serve as plausible Agents and Patients for 240 transitive verbs. Example sentence initial phrases are shown below. The gardener/juice had soaked... [Active] The sailor/carpet was soaked... [Passive] In order to prevent auxiliary verbs from predicting voice, additional sentences were created using alternative active and passive structures (i.e. ...was soaking [Active] and ...had been soaked [Passive]). Across all experimental lists each verb appeared in both active and passive voice, and each subject NP appeared as both an Agent and Patient. Critical verbs were matched on latent semantic association (LSA) to their preceding context in all conditions. RESULTS: Grammatical voice rapidly affected verb processing, as indicated by a right lateralized negativity peaking at 225msec over right temporal sites. This was followed by a left lateralized positivity starting at approximately 400msec and peaking over left temporal regions at approximately 700msec. Processing of grammatical voice was unaffected by subject NP animacy. However, verbs following inanimate (versus animate) NPs evoked a late, broadly distributed positivity peaking at central sites at approximately 700msec. DISCUSSION: Our data indicate that the passive voice may induce processing costs as early as word form identification, continuing during later processing. The passive related positivity appears to be neither the P345 nor the P600, based on its time-course and scalp distribution, respectively. This suggests that the cost of processing the passive voice is neither based on difficulty in initially computing the link between syntactic arguments and thematic roles nor with syntactic reanalysis. Additionally, our data suggests animacy is a factor affecting verb processing which is independent of thematic roles assignment. CONCLUSIONS: Our data demonstrate that the passive voice is associated with a unique pattern of neural activation, distinct from that previously reported for syntactically assigning or reassigning thematic roles. References Ferreira, F. (2003). *Cognitive Psychology*, 47, 164–203. Trueswell, Tanenhaus & Garnsey (1994), *Journal of Memory and Language*, 33, 285-318.

101. ERP evidence that local nouns affect subject-verb agreement processing. E.Y. Shen (1), A. Staub (2), L. Sanders (1,2). (1) University of Massachusetts, Neuroscience and Behavior Program, Amherst, US. (2) University of Massachusetts, Department of Psychology, Amherst, US.

Objective: In English, a subject and its verb must agree in number for a sentence to be considered grammatical. Having a local noun or phrase that bears additional number properties (i.e., singular or plural) inserted between a subject and a verb results in frequent production errors and may complicate receptive language processing as well. Previous event-related potential (ERP) studies have shown that syntactic violations typically elicit a left anterior negativity (LAN) that peaks between 100 and 300 ms. When participants are asked to make grammaticality judgments, the violations also elicit a posterior positivity that peaks around 600 ms (P600). The current study employs ERP indices to investigate whether local nouns play a role in subject-verb agreement processing during natural speech comprehension. Method: Participants were asked to listen to four short stories that included a very low proportion of subject-verb agreement violations. Each listener heard either the canonical or violation

version of three types of sentences ($N = 35$): no local noun, head and local nouns that were both singular, and a singular head noun followed by a plural local noun. (1) SS: She calls and says for us to come eat with her. (2) SP: She call and says for us to come eat with her. (3) SSS: A catalogue with a color picture sits in front of her. (4) SSP: A catalogue with a color picture sit in front of her. (5) SPS: A catalogue with color pictures sits in front of her. (6) SPP: A catalogue with color pictures sit in front of her. Twenty adults were asked to press a key immediately when they heard anything abnormal. For a different twenty-four adults, EEG was recorded while they listened to the narratives to answer comprehension questions presented at the end of each story. Results: Listeners were able to detect all three types of violations, though performance was better with no local noun ($d' = 2.71$, SS/SP) than for either the singular ($d' = 2.26$, SSS/SSP) or plural ($d' = 1.29$, SPS/SPP) local noun. ERPs time-locked to the ends of critical words were compared. As expected, simple subject-verb agreement violations (SP compared to SS) elicited an anterior negativity 150-300ms and a posterior positivity 700-950 ms. These effects were not evident when a similar (SSP compared to SSS) or contrasting (SPP compared to SPS) local noun was present between the subject and verb. However, when the inserted local noun contrasted with the head noun in number, the ends of verbs elicited a posterior positivity between 150 and 300 ms regardless of subject-verb agreement (SPS compared to SSS and SPP compared to SSP). Conclusion: Local noun insertions affect receptive language processing of subject-verb agreement under ecologically valid listening conditions. Automatic detection of the violations, as indexed by the LAN, is disrupted. Additional processing demands, as indexed by the early posterior positivity, are introduced.

102. Selection for position: The role of left inferior frontal gyrus (LIFG) in sequencing nouns. M. Thothathiri (1,2), M. F. Schwartz (1), S. Thompson-Schill (2). (1) Moss Rehabilitation Research Institute, Philadelphia, US. (2) University of Pennsylvania, Philadelphia, US.

LIFG patients famously show syntactic deficits. They also show greater interference in serial recall and semantic blocking studies. Conceivably, both deficits could arise from inadequate biasing of competitive interactions during language production. To test this hypothesis, we manipulated "positional" interference during multiword naming by priming one of the nouns in the same or different position. We hypothesized that LIFG patients would show heightened interference compared to controls. Based on previous results (Schnur, Schwartz, Kimberg, Hirshorn, Coslett & Thompson-Schill, 2009) we also predicted that damage to dorsal BA 44 might be particularly relevant. Participants. Four patients with substantial damage to LIFG (BA 44, 45 and 47) and minimal damage to posterior language areas participated. All were proficient in single word naming (Philadelphia Naming Test: 88-95% accuracy). Six healthy controls (age: 52-70) also were tested. Methods. On each trial, participants named two pictures shown on a computer using a simple "x and y" phrase. Pictures disappeared upon speech onset, encouraging concurrent planning of the two nouns. Each session contained 2 blocks. Each block contained 200 naming trials. This included 40 3-trial sets ("triads") in which one of the nouns repeated. On the first two trials of the triad, the repeated noun always appeared in the same position (first or second, 50% each). On the critical third trial, it either stayed in the same position ("consistent") or switched ("inconsistent"). We measured naming latency from digital recordings. We calculated baseline RTs from 120 non-repeat trials in each block (80 fillers and 40 first trials in triads). For the critical trials, normalized RTs were calculated as $(RT - \text{Baseline}) / \text{Baseline}$. This controlled for baseline RT differences across participants. Our interference measure was $(\text{Normalized RT on inconsistent}) - (\text{Normalized RT on consistent})$ trials. Patient means were calculated from two sessions, control means from one session. Results & Discussion. Two patients (TB, CBD) showed heightened interference effects in RTs (>1 SD) compared to controls; the remaining two (MD, UT) did not (Fig. 1a). On non-repeat trials, the former group made more omissions (Fig. 1b) but fewer errors overall when animacy was a useful cue for sequencing (Fig. 1c). As predicted, damage to dorsal BA 44 separated the former from the latter (Fig. 1d). Our results extend the biasing competition hypothesis for LIFG to a sequencing task, and indicate a more precise anatomical locus. Damage to dorsal BA 44 (border of 44 and 6) identified a subgroup of LIFG patients who showed greater positional interference and overall difficulty with multiword naming. These results suggest that LIFG's role in syntax may include selection for position. References Schnur, T. T., Schwartz, M. F., Kimberg, D. Y., Hirshorn, E., Coslett, H. B., & Thompson-Schill, S. L. (2009). Localizing interference during naming: Convergent neuroimaging and neuropsychological evidence for the function of Broca's area. *PNAS*, 106(1), 322-327.

Poster Session B

Friday, October 16 2009, 4:15 – 6:45 p.m., Halsted Room.

ABSTRACTS

Speech perception

1. Rate and Local Reversal Effects on Speech Comprehension. V. Figueroa (1) (2) M. Howard (2) B. Idsardi (2) D. Poeppel (2) (3). (1) Pontificia Universidad Catolica de Chile, Santiago, Chile. (2)University of Maryland, College Park, US. (3)New York University, New York, US.

Previous research suggests that the brain samples the incoming speech signals in discrete time frames corresponding to the timing of relevant linguistic units, namely phonemes and syllables (Poeppel, 2003). This study explores the temporal constraints of speech processing, and their relation to the way basic linguistic units are represented by the cognitive system. Studies on locally reversed speech, show some evidence that supports the phoneme size scale time window as relevant for speech integration (Saber, 1999; Greenberg & Arai, 2001). In order to further test temporal constraints on speech processing, two combined manipulations of spoken sentences were used: rate modification and local reversals of the speech signal. Presentation rate of each sentence was modified by compressing and stretching the acoustic signal by a factor of 0.5 and 1.5, respectively. In addition, the acoustic signal was locally reversed in window sizes ranging from 20 ms to 100 ms. Finally, a condition without reversal was included. Participants were assigned to one of three different rate conditions, and presented with four different sentences for each reversal window size. The task consisted in listening to the sentences and then typing them up. Intelligibility was measured as the percent of words correctly identified. Results for normal speech replicate previous studies (Greenberg & Arai, 2001), showing intelligibility decreases to 50% for 65 ms reversal windows. For the other rates, as expected, subjects show a decreased performance for compressed speech and an increased one for stretched speech, as compared to normal speech. Performance for compressed speech reaches 50% at reversal window size of 35 ms, on the other hand the same performance is reached at 85 ms for stretched speech (see figure-1). Interestingly when comparing equivalent time windows considering the same proportion of the total sentence time comprised by the reversals, performance for compressed speech is significantly better than performance for normal speech, on the contrary, performance for stretched speech is significantly worse. Results show that for compressed speech reversal windows of 50 ms, average performance reached 32 % , this score is significantly higher compared to the 9% intelligibility obtained at an equivalent window of 100 ms for normal speech stimuli. On the other side, for stretched speech reversal windows of 100 ms, average performance reached 23 % , this score is significantly lower compared to the 37% intelligibility obtained at an equivalent window of 70 ms for normal speech stimuli. As observed in normal rate speech, comprehension starts to be severely compromised when the window sizes gets close to phonemic units size. Interestingly, results for different compression rates, suggest that even when the perceptual system can adapt to the temporal properties of heavily distorted speech inputs, it also has inherent properties that constrain this tuning. These results are consistent with the neural model of speech perception proposed by Poeppel (2003), suggesting that the brain preferentially samples at rates tuned to fundamental speech units.

2. MEG evidence for non-uniform perceptual sensitivity in vowel space. P. M. Alcocer (1), B. W. Dillon (1), W. J. Idsardi (1,2) (1) Department of Linguistics, University of Maryland, College Park, US. (2) Neuroscience and Cognitive Science Program, University of Maryland, College Park, US.

We report magnetoencephalographic (MEG) evidence that the M100 response is sensitive to interactions between first and second vowel formants (F1, F2) frequencies. Two F1 (500 Hz, 700 Hz) and two F2 values (1100 Hz, 1900 Hz) were chosen and crossed to give four different American English vowel categories /[^]/ (500Hz/1100Hz), /E/ (500Hz/1900Hz), /a/ (700Hz/1100Hz), and /ae/ (700Hz/1900Hz). Four synthetic tokens were generated from these crossings. Comparison of participants' M100 responses to these stimuli revealed a significant effect of F2 and a significant interaction of F1 and F2 values. Subsequent pair-wise comparisons revealed the source of the effects: /ae/ was significantly delayed relative to /a/, and there were additional marginally significant delays of /E/ and /[^]/ relative to /a/. The pattern of results suggests that neither F1 nor F2 is the primary factor modulating M100 latency. Rather /a/ tentatively appears to have a privileged status with respect to the other vowels in the study. If the view that the tonochronic properties of the M100 are largely predicated on formant structure is to be maintained, then the current set of results suggests a hypothesis that is grossly consistent with the view outlined by Ohi and Scheich (1997) and Diesch and Luce (2000), where it is claimed that the auditory cortex does not specifically resolve different formant peaks, but rather that the auditory cortex tracks a single value that represents a transform of the F1 and F2 values.

3. Asymmetric on-line predictions in speech perception: MEG evidence. S. Hwang (1), P. Monahan (2), and W. Idsardi (3). (1) University of Maryland, College Park, MD US. (2) University of Maryland, College Park, MD US. (3) University of Maryland, College Park, MD US.

Purpose: A major challenge for listeners in speech perception is to map highly variable input onto invariant phonological

representations. Fine acoustic detail, however, also provides information about surrounding phonetic segments. The analysis of auditory input involves a fast mapping to candidate abstract forms and the subsequent generation of predictions of upcoming material via the forward generative model (Stevens & Halle 1964; Poeppel, Idsardi & van Wassenhove 2008). Using MEG, we examine the time course of predictions of the upcoming signal based on available phonetic cues. Our findings suggest that early auditory cortical processing (as indexed by the M100) is sensitive to violations of phonotactic predictions derived from higher-order linguistic knowledge. Background: Some sound sequences are permitted in natural language (e.g., English words can begin with [tr]), while others are not (e.g., English words cannot begin with [rt]). Previous MEG research has revealed processing asymmetries in illicit sequences involving mismatches of nasalization (Flagg, et al. 2005) and voicing (Hwang, et al submitted). Here, we report new asymmetries in the early cortical responses to sequences that violate rules of tongue position. These previous findings are consistent with the theory of phonological underspecification, in which certain values for speech parameters (voicelessness, orality, etc.) are systematically absent in the abstract representational scheme. Experiment: In English, the dorsal plosive [g] is produced further forward in the mouth ([g+]) when preceding FRONT vowels (e.g., [I e]) than when preceding BACK vowels (e.g., [A U]). Obleser et al (2004) report an asymmetry between front and back vowels and attribute that effect to the underspecification of frontness in vowels. In the current experiment, stimuli were matched or mismatched for place of articulation by splicing or cross-splicing [Vf] frames onto [g] and [g+]. Subjects (n= 10) were asked to identify the vowel they heard while their brain activity was recorded (MEG 157-channel whole head axial gradiometer, KIT, Japan). If listeners can use the allophonic information from the consonant to make predictions about the upcoming vowel, then we expect them to show difficulty with the mismatch items. Results: We find a reliable difference in the M100 peak latency comparing [g(A U)] (match, shorter latency) and [g+(A U)] (mismatch, longer latency) ($p < 0.05$) but no difference between [g+(I e)] (match) and [g(I e)] (mismatch) ($p < 0.34$) or any of the behavioral responses. Conclusion: We conclude that the acoustic cues on [g] and [g+] are used to make predictions about the upcoming vowel, but only the marked (i.e., back) vowels contained cues on which predictions could be evaluated. Our results suggest that phonological knowledge can serve as the basis for predictions in online speech perception, and violations of these predictions are reflected in early cortical processes. As predicted by models of underspecification, only the specified back vowels, and not the underspecified front vowels, played a role in processing. Although the M100 is often regarded as an early, low-level response to auditory stimuli, our findings further demonstrate that it can reflect the integration of higher-level phonological knowledge about constraints on speech sound sequences with bottom-up acoustic cues.

4. Neural correlates of understanding time-reversed cheeps: an ERP study. V. Boulenger (1), C. Jacquier (1), M. Hoen (2), and F. Meunier (1) (1) Laboratoire Dynamique du Langage CNRS UMR 5596, Lyon, France. (2) Stem Cell and Brain Research Institute INSERM U846, Lyon, France.

Under ecological conditions, speech is hardly ever perceived in ideal acoustic conditions: our neurocognitive system must often cope with transient signal perturbations such as sudden breaks, mispronunciations or interfering noises. The cerebral mechanisms allowing the listener to react in real-time to such fast and unexpected perturbations in order to maintain intelligibility of the delivered message are still partly unknown. The present electroencephalography (EEG) study aimed at investigating the neural processes that come into play during real-time detection and cognitive reconstruction of a sudden acoustic distortion occurring in connected speech. We explored the dynamics of cortical responses, as measured by the recording of event-related potentials (ERPs), underlying the processing of increasingly degraded portions of speech embedded in sentences. Healthy participants were instructed to listen to and to repeat sentences, in which the final word could contain "the most drastic form of speech distortion", that is, signal reversions along the temporal dimension (reversed speech) of varying durations. Predictability of this sentence-final word was also manipulated in order to examine potential interactions between this semantic dimension and ERPs characterizing speech restoration. Behavioral results showed high comprehension rates even in largely reverted conditions, confirming the existence of perceptual and comprehension mechanisms robust to quite remarkable temporal reversions. EEG results revealed that processing of these transient acoustical distortions of the signal was associated with two ERP signatures. An early negative wave peaking approximately 250 ms after degraded word onset and maximal over frontal sites (Fz) was observed. Interestingly, this component had the same dynamic and topography characteristics as the acoustic Mismatch Negativity (MMN), recorded in the same subjects during an oddball paradigm, and known to reflect the detection of sudden acoustic variations. This wave was followed by a second sustained and long-lasting positive wave with maximal amplitude over fronto-central sites and peaking around 500 ms after word onset. Amplitude of this late component was modulated by the size of the temporal reversion, the larger the distortion, the larger the amplitude. We suggest that the early negative wave, reflecting rapid detection of speech-specific distortions, may be labeled an MMN and that it may play a role in speech-in-noise or distorted speech comprehension. This would allow the system to trigger on-line compensatory mechanisms that can correct for degraded or missing information and ease the final comprehension of an acoustically imperfect message. These reconstruction mechanisms may be reflected by the late observed component. Understanding degraded speech requires the rapid integration of multiple contextual cues (which would be easier for predictable sentence-final words) to replace or repair the wrong or missing information for coherent interpretation. These reconstruction strategies engaged after the detection of a transient reversed portion of speech in a word may occur in such a late time-window. In conclusion, our findings show a clear distinction between two neural mechanisms that would participate in the comprehension of degraded speech. They establish a link, in the context of natural speech comprehension, between transient acoustical perturbation detection and on-line compensation of missing information in the context of auditory

sentence comprehension.

5. Emergent categorical representation of phonemes in the human superior temporal gyrus. E. F. Chang (1), J. W. Rieger (1), A. Flinker (1), K. Johnson (1), N. M. Barbaro (1), R. T. Knight (1). (1) University of California, San Francisco, US.

The partitioning of continuously variable acoustic signals into discrete perceptual categories is a fundamental feature of human speech. Despite the importance of categorical perception, the neural correlates underlying this phenomenon await identification. We used a customized high-density cortical array to record direct surface local field potentials in two awake humans undergoing neurosurgical procedures. Phonetic stimuli were synthesized with warped acoustic features across the /ba/-/da/-/ga/ continuum by parametric alteration of the F2 formant frequency (14 tokens). Passive listening to phonetic stimuli revealed robust and distributed neural population activation over the posterior superior temporal gyrus manifested in early- and mid-latency (20-50msec) components. Pairwise comparisons between responses to each stimulus demonstrated significant differences in longer-latency components of waveforms (about 100-120 msec after stimulus onset). Support Vector Machine classification was used to create a confusion matrix to estimate the pattern of representational dissimilarity arising from phoneme responses. The results of this analysis demonstrated spatiotemporally-specific cortical activation organized along categorical, but not continuous dimensions of the acoustic continua. Furthermore, cluster analysis of response features demonstrated independence between categories, supporting a phonetic over acoustic representation of speech. The categorical boundaries from neural data correlated with subject-specific behavioral discrimination and identification functions. These results advance our current understanding of the cortical substrates underlying speech perception.

6. Laminar cortical dynamics of conscious speech perception: Phonemic restoration in noise using subsequent context. S. Kazerounian (1), S. Grossberg (1). (1) Boston University, Cognitive and Neural Systems, Boston, US.

Objective. How are the laminar circuits of neocortex organized to generate conscious percepts of speech and language? How does the brain restore information that is occluded by noise using the context of a word or sentence? How is the meaning of a word or sentence linked to such a restoration process? Phonemic restoration exemplifies the brain's ability to complete and understand speech and language in noisy environments. Phonemic restoration can occur, for example, when broadband noise replaces a deleted phoneme from a speech stream, but is perceptually restored by a listener despite being absent from the acoustic signal (Warren 1970; Warren & Warren 1970). Moreover, the phoneme to be restored can depend on subsequent context (Warren & Sherman, 1974). Methods. A laminar cortical model is presented which clarifies the brain's ability to complete a percept that is occluded or replaced by noise on the basis of bottom-up and top-down contextual interactions that operate across hundreds of milliseconds. The model clarifies how a conscious speech percept develops forward in time even in cases where future events control how previously presented acoustic events are heard. The model predicts how multiple processing stages interact to generate a conscious speech percept. In particular, acoustic features are unitized into acoustic items. These items activate representations in a sequential short-term working memory. The sequence of stored working memory items interacts reciprocally with unitized representations of item sequences, or list chunks. These multiple levels interact, in turn, through positive feedback to generate a resonant wave of activation whose attended features embody the consciously heard percept. Results. Model simulations clarify why the presence of noise is necessary for restoration to occur, and why in the absence of noise a silence gap is perceived. Discussion. These resonance properties are traced to the brain's ability to rapidly and stably learn language. The model shows how these properties may be embodied in laminar cortical circuits whose variations have elsewhere been used to quantitatively explain data about cognitive working memory and visual perception. Supported in part by CELEST, an NSF Science of Learning (SBE-0354378) and by the DARPA SyNAPSE program HR0011-09-3-0001 and HR0011-09-C-0011).

7. Neural correlates of informational masking in cocktail party situation. M. Dole (1), M. Hoen (2), F. Meunier (1). (1) Laboratoire Dynamique du Langage, CNRS UMR5596, Lyon, France (2) Stem Cell and Brain Research Institute, INSERM U846, Lyon, France

The cocktail party effect refers to situations in which people must segregate between competing auditory sources; one situation of particular interest in this context is speech-in-speech comprehension. In such situations, two types of masking effect can be described: energetic masking (EM), produced when the target signal and interfering noise partly overlap in time and frequency; and informational masking (IM), which occurs when information inside the target signal and the interfering noise is of comparable nature and become difficult to disentangle. Typically, IM occurs more prominently when the competing flows are speech sounds. Previous behavioural studies showed that IM occurring during speech-in-speech comprehension consisted of different levels of competitions, including an acoustic-phonetic competition and a lexical competition reflected in the increase of masking when noise was natural speech in contrast with reversed speech (Hoen et al., 2007). Up to now, few studies investigated the cortical activations associated with speech-in-speech comprehension; amongst those, Scott and colleagues in 2004, used PET to investigate cortical activations associated with IM. They compared functional activations associated with speech-in-noise comprehension, using two types of noise: unmodulated noise, principally producing EM, and babble noise, producing both EM and IM. They showed increased activations in bilateral temporal superior gyri associated with IM, whereas EM involved a neural network including right posterior parietal cortex, left dorso-lateral prefrontal cortex, and left frontal pole. To further characterize cortical networks involved in IM, we used interleaved silent steady state (ISSS) imaging

(Schwarzabuer et al., 2006), to evaluate cortical activations in a speech-in-noise task. To dissociate the different levels of IM, three types of noise were used: a speech-derived Broadband Noise (Noise condition) producing pure EM of the same magnitude as all following sounds, a 4-talkers babble noise (Cocktail), and the same babble sound but reversed along its temporal axis or reversed babble, keeping some phonetic cues but no lexical or semantic information (Reverse). Baseline was obtained by presenting stimuli in silence (Silence). Subjects were asked to carefully listen to stimuli composed of words embedded in these different noises; then, two words were presented on a screen and participants had to select the words they heard. We obtained better behavioural scores in the Noise condition in comparison with the Babble and Reversed Babble conditions. In agreement with our hypothesis, scores were also better in Reversed condition than in Babble condition, since IM is reduced in this latter condition. Concerning BOLD responses, cortical activations show different networks implicated in speech-in-noise vs. speech-in-speech comprehension. Pure EM (noise vs. silence) seems to engage parietal regions suggesting increased attentional processes whereas IM (cocktail vs. noise) seems to occur in speech intelligibility related areas, mostly along the superior temporal gyrus. Moreover the speech-in-speech condition (cocktail vs. noise) seems to engage different regions in the superior temporal lobes of the two hemispheres. These results will be discussed in the light of recent results on processing temporal vs. spectral information in speech comprehension (Obleser et al., 2008) and in the general context of specifying IM in cocktail party situations.

8. Modulation of cortical speech representations by selective attention in a “cocktail party”. *L.M. Miller (1), J.R. Kerlin (1), and A.J. Shahin* (1,2). (1) University of California, Davis, CA, U.S. (2) Present address for A.J. Shahin: Ohio State University, Columbus, OH, U.S.*

Objective: Our ability to actively select a single talker in an environment with multiple competing speech sounds is a remarkable perceptual feat. While many studies have sought to identify the neural mechanism of selective attention to transient sounds, very few have addressed the unique nature of selecting speech as a temporally extended and complex auditory object. In the present study, we hypothesized that sustained selective attention to a particular speech stream in a multi-talker environment would act as a gain control mechanism on the early auditory cortical representations of speech, and sought to characterize this mechanism with high-density electroencephalography (EEG). Methods: During 128-channel EEG recording, fourteen participants listened to sentences lateralized in virtual space to the left and right. Each utterance comprised one of two possible sentence templates (“Brandon’s wife seemed”, “His other friend got the”) ending with an unpredictable final word. The different sentences were presented either alone (Single Talker Condition) or simultaneously (Dual Talker Condition) while subjects were cued to attend to only one sentence in one direction for each trial, or to listen passively. Subjects were instructed to determine the syntactic congruency of the final word of the attended sentence. Behavioral measures, event-related potentials, and task-related changes in EEG spectral power were collected and compared to assess how processing of spatial location and speech content are modulated by sustained auditory attention. Specifically, we correlated the average difference in the response to the two sentences across all subjects in the Single Talker Condition with the response to the attended and unattended sentences in the Dual Talker Condition, producing an attentional correlation index (ACI). A signal source based on the early auditory ERP response was also used as a filter for the continuous EEG response. Results: The EEG signal produced while attending in the direction of a particular sentence in the Dual Talker Condition (e.g. “Brandon’s wife seemed”) significantly correlated with the template from the Single Talker Condition for that sentence. The scalp topography of the ACI is strongly consistent with that of an early auditory source, was greatest at a signal frequency of 4-8 Hertz, continued throughout the sentence and peaked near the end of the sentence. The ACI increased for the matching attended sentence and decreased for the unattended sentence, compared to passive listening. Hemispheric lateralization of parietal alpha power at sentence onset in the Dual Talker condition was significantly correlated with the ACI. Conclusions: Evidence from the current study provides a direct link between the neural representation of a sentence and attention to that sentence in a multi-talker environment. The selection of speech appears to act through a mechanism of continuous enhancement of the attended signal and suppression of the unattended signal in early auditory cortex. We propose a process in which alpha lateralization facilitates spatial selection of an auditory stream, the stream’s representation is continuously enhanced and its competition suppressed in auditory cortex, leading to increased comprehension.

9. Contextual blending of ingroup/outgroup face stimuli and word valence: LPP modulation and convergence of measures. *E. Hurtado (1,4), A. Haya (5), R. Gonzalez (1,5), F. Manes (3) and A. Ibañez (1,2). (1) Laboratory of Cognitive Neuroscience, Universidad Diego Portales, Santiago, Chile (2) CONICET, Argentina (3) Institute of Cognitive and Behavioural Neurology (INECO), Argentina (4) School of Engineering, Pontificia Universidad Catolica de Chile (5) School of Psychology, Pontificia Universidad Catolica de Chile.*

Several event related potential (ERP) studies have investigated the time course of different aspects of evaluative processing in social bias research. Various reports suggest that the late positive potential (LPP) is modulated by the basic evaluative process, and some reports suggest that in-/outgroup relative position affects ERP responses. In order to study possible LPP blending between facial race processing and semantic valence (positive or negative words), we recorded ERPs while indigenous and non-indigenous participants who were matched by age and gender performed an implicit association test (IAT). The task involved categorizing faces (ingroup and outgroup) and words (positive and negative). Since our paradigm implies an evaluative task with positive and negative valence association, a frontal distribution of LPPs similar to that found in previous reports was expected. At the same time, we predicted that LPP valence lateralization would be modulated not only by positive/negative

associations but also by particular combinations of valence, face stimuli and participant relative position. Results showed that, during an IAT, indigenous participants with greater behavioral ingroup bias displayed a frontal LPP that was modulated in terms of complex contextual associations involving ethnic group and valence. The LPP was lateralized to the right for negative valence stimuli and to the left for positive valence stimuli. This valence lateralization was influenced by the combination of valence and membership type relevant to compatibility with prejudice toward a minority. Behavioral data from the IAT and an explicit attitudes questionnaire were used to clarify this finding and showed that ingroup bias plays an important role. Both ingroup favoritism and indigenous/non-indigenous differences were consistently present in the data. Our results suggest that frontal LPP is elicited by contextual blending of evaluative judgments of in-/outgroup information and positive vs. negative valence association and confirm recent research relating in-/outgroup ERP modulation and frontal LPP. LPP modulation may cohere with implicit measures of attitudes. The convergence of measures that were observed supports the idea that racial and valence evaluations are strongly influenced by context. This result adds to a growing set of evidence concerning contextual sensitivity of different measures of prejudice. Overall, our results present a view of prejudice in which different measures and moments of the process show coherence.

10. Functional connectivity from auditory and visual cortex to multisensory superior temporal sulcus during audiovisual speech depends on modality reliability. A. Nath (1), M. Beauchamp (1). (1) *University of Texas Medical School at Houston, Houston, US.*

Multisensory integration (MSI) is critical for understanding audiovisual (AV) speech. A multisensory region within the human superior temporal sulcus (STSms) is thought to be important for MSI of AV speech. The reliability of auditory and visual cues can vary greatly, but little is known about how the STSms combines unisensory inputs of differing reliability. To investigate this problem, we measured functional connectivity between auditory cortex, visual cortex and STSms during perception of auditory-reliable (Aud-Rel) and visual-reliable (Vis-Rel) AV single-syllable words with BOLD fMRI at 3T. Aud-Rel speech was created by degrading the visual stimulus with a Gaussian blur and Vis-Rel speech was created by degrading the auditory stimulus with a noise-vocoder. Auditory, visual and STSms regions of interest (ROIs) were created in each subject based on activation during blocks of undegraded unisensory auditory or visual words. Then connectivity was measured between these ROIs during presentation of degraded AV words. In experiment 1, nine subjects were presented with blocks of Aud-Rel and Vis-Rel AV words. The predicted BOLD response was subtracted from each BOLD time series (to remove high-amplitude block responses that could artificially inflate correlations), and connectivity was measured as the correlation coefficient between residuals from each ROI. During Aud-Rel stimuli, connections to STSms were stronger from the auditory ROI than the visual ROI (0.61 vs. 0.56, $p < 0.02$). During Vis-Rel stimuli, connections to STSms were stronger from the visual ROI than the auditory ROI (0.57 vs. 0.53, $p < 0.001$). In the block design of experiment 1, these correlations may have been driven by selective attention to the undegraded modality in each block. Therefore, a second experiment with nine subjects was performed in which stimuli were presented in a rapid event-related design with Aud-Rel and Vis-Rel AV words randomly intermixed. Separate beta-weights for each stimulus were calculated using a GLM and then the correlation coefficient was calculated between the ROI beta-weights. During Aud-Rel stimuli, connections to STSms were stronger from the auditory ROI than the visual ROI (0.52 vs. 0.44, $p < 0.01$). During Vis-Rel stimuli, connections to STSms were stronger from the visual ROI than the auditory ROI (0.50 vs. 0.44, $p < 0.01$). Across two experiments in fourteen subjects, the STSms was more strongly connected to unisensory regions corresponding to the undegraded input modality during presentation of one undegraded and one degraded input modality. These findings suggest that STSms takes into account the quality of incoming speech information from each modality during integration.

11. Spectro-temporal encoding of speech by ECoG signals in human auditory and frontal cortices.

S. V. David(1), B. N. Pasley (2), N. Mesgarani (1), A. Flinker (2), E. F. Chang (3), N. E. Crone (4), S. A. Shamma (1), R. T. Knight (2). (1) *University of Maryland, College Park, Maryland, US* (2) *University of California, Berkeley, California, US* (3) *University of California, San Francisco, California, US* (4) *Johns Hopkins University School of Medicine, Baltimore, Maryland, US.*

Research in non-human mammals has described the spectro-temporal representation of speech and other natural sounds in cortex, but little is known about how these findings generalize to humans. To study auditory representation in humans, we recorded electrocorticographic signals (ECoG) from epileptic patients during a 24 hour period. Subdural recordings were made using a 10 x 8 or 8 x 8 grid of electrodes (spacing 10 mm) placed over language-dominant temporal and frontal lobes. Patients were presented with a sequence of speech sounds (isolated words and sentences) during passive listening. To study the representation of the speech sounds, spectro-temporal receptive fields (STRFs) were estimated using time-varying high gamma power (100-300 Hz, 10 ms time bins) at each ECoG site. The STRF is a frequency-time tuning function that provides the minimum mean-squared error linear prediction of neural activity in response to an arbitrary auditory stimulus. STRFs were estimated by normalized reverse correlation, a procedure that compensates for spectro-temporal correlations present in speech and other natural sounds that can bias STRFs estimated using other methods. Several sites along the lateral surface of the superior temporal gyrus showed clear tuning to spectro-temporal sound features, and the corresponding STRFs were able to predict high gamma activity in a validation data set with correlations up to $r=0.4$. STRFs measured from power at lower ECoG frequencies and from the raw signal showed much weaker spectro-temporal tuning, and high-gamma STRFs performed consistently better. Preliminary topographic data suggested a tonotopic organization of some auditory sites, which may require finer-scale recordings for confirmation. For a small number of sites in motor areas of frontal cortex, STRFs also had significant

predictive power, suggesting that these areas may also participate in processing the basic features of speech. A large number of sites in temporal cortex that could not be characterized with STRFs did show phase-locked responses to auditory stimuli. Characterization of tuning at these sites may require nonlinear spectro-temporal models or models that incorporate high-level abstract sound features.

12. Neural correlates of sonority sequencing constraint violations in word-initial consonant clusters using MEG.

P.M. Alcocer (1), E. Jensen (2), S. Kratovac (2), A. Lukyanchenko (3), S. Teubner-Rhodes (2), D. Poeppel (4), W.J. Idsardi (1, 2). (1) Department of Linguistics, University of Maryland, College Park, US. (2) Neuroscience and Cognitive Science Program, University of Maryland, College Park, US. (3) Second Language Acquisition Program, University of Maryland, College Park, US. (4) Department of Psychology, New York University, US.

To what extent does our knowledge of the constraints governing the sequencing of speech sounds influence early auditory cortical processing? Sonority is a property of speech sounds that is associated with their relative loudness and resonance. Across languages, it has been observed that in word-initial consonant clusters, less sonorant sounds tend to be followed by more sonorant sounds, and not the reverse (e.g., [dl] is more common than [ld]). This preference for an increasing sonority slope across a cluster has been called the sonority sequencing constraint (SSC). Using MEG and the magnetic mismatch field response (MMF), we investigate whether a preference for consonant clusters of rising sonority resulting from the SSC is reflected in early automatic processing in the auditory cortex. Berent et al. (2008), in a behavioral study, found that Korean speakers perceived monosyllabic words with word-initial consonant clusters of falling sonority, but not rising sonority, as disyllabic, suggesting a possible repair operation that inserted an epenthetic vowel in these clusters. Because in Korean all consonant clusters are illicit word-initially, Korean speakers should have no experience-based preference for rising or falling sonority in word-initial clusters. The present study attempts to replicate the findings of the previous study in the neural response using word-initial clusters of rising and falling sonority that are illicit in English ([dl], [ld]). We employ an MMF-eliciting design comparing the neural response to [dlif] and [delif] in the rising sonority condition and [ldif] and [ledif] in the falling sonority condition. Stimuli were created by recording disyllabic tokens ([delif] and [ledif]) and splicing out the first inter-consonantal vowel. Native English-speaking participants (n=6) passively listened to stimuli presented in an oddball paradigm during MEG recording (160-channel whole-head-axial-gradiometer MEG system; KIT, Japan). Four blocks were run: two using monosyllabic tokens as the standard and two using disyllabic tokens as standard. We find that the rising sonority tokens consistently elicit an MMF with an onset at 200ms (standard vs. deviant, $t = -17.58$, $p < 0.01$, $t = -22.04$, $p < 0.01$), suggesting that participants are able to perceptually distinguish [dlif] from [delif]. Crucially, however, we find no MMF response for [ldif] as deviant ($t = 1.54$, n.s.), suggesting that participants do not perceive the difference between [ldif] and [ledif]. This finding indicates that the SSC is operative early in phonological processing and can influence early automatic responses in auditory cortex.

13. Spatio-Temporal Dynamics Of Ventral And Dorsal Pathways For Language: Intracerebral Erp Study In Semantic And Phonological Monitoring Task.

A. Trebuchon-Da Fonseca (1), J.F. Demonet (2), J. Regis (1), P. Chauvel (1), C. Liegeois-Chauvel (1). (1) INSERM U751, Université de la Méditerranée, Assistance Publique-Hôpitaux de Marseille, Marseille, FRANCE (2) INSERM U825, Pôle de Neurosciences, CHU Toulouse, FRANCE

Introduction: Supported by neuroimaging studies, recent theory of physiology of language suggests a dual stream model organisation: a dorsal stream involved in mapping sound to articulation or acoustico-phonological processes, and a ventral stream involved in mapping sound to meaning or lexico-semantic processes. The aim of this study was to explore different brain regions constituting ventral and dorsal pathways in order to define the spatio-temporal dynamic of this dual stream processing. **Material and Methods:** Intracranial recordings (stereo-electroencephalography, SEEG) were performed in pre-surgical assessment of fifteen drug-resistant epileptic patients. Event Related Potentials (ERPs) were recorded during both lexico-semantic and phonological monitoring tasks. In the lexico-semantic task, patients had to select from pairs of words comprising an adjective followed by an animal name, and were instructed to choose the pair in which the adjective was positive and the animal was smaller than a rabbit. In the phonological task, patients had to select from pairs of pseudowords, and were instructed to choose the pair in which the first pseudoword contained the phoneme /d/ and the second pseudoword contained the phoneme /b/. **Results:** In the left-dominant hemisphere lexical status (word and pseudo-word) as well as the electrophysiological signature elicited by phonological and lexico-semantic tasks were different in ventral stream (temporal regions), dorsal stream (inferior parietal region) and frontal regions. Only the lexico-semantic monitoring task yielded a significant modulation of two components in the ventral stream: a N400 and a late component, LC700. The N400 modulation started at 250-300 ms in the posterior part of the MTG, then in the anterior temporal region from 350 ms, finishing at 600 ms in inferior frontal region. The LC700 modulation started at 500-650 ms in the posterior part of temporal region and finished at 600/850 ms in the anterior part. In the dorsal stream (SMG), only the phonological task elicited significant modulation of two components: the first, occurring between 220 to 400 ms, was called PMN-L and a LC700. The modulation of the LC700 started at 650 ms in pSMG and finishing at 900 ms in aSMG. No response was clearly identified in the symmetric-anatomical-defined sites of the responsive regions. **Conclusion:** In the present study, using intracranial recordings in the various parts of the ventral and dorsal network, we evidenced for the first time the dual stream processes involving in speech perception detailed simultaneously in both time and space. Linguistic processes differently involved both networks with the phonological task modulating responses in dorsal network, whereas the lexico-semantic task modulated responses in

ventral network. Finally, we observed that both networks were strongly left lateralized.

14. The effects of training on lexical tone perception: A time/frequency analysis. E. Kaan (1), W. Kara (1), R. Wayland (1) and A. Keil (2) (1) *Linguistics, University of Florida, Gainesville, US.* (2) *Psychology and NIMH Center for the Study of Emotion & Attention, University of Florida, Gainesville, US.*

Tone languages such as Thai and Mandarin Chinese use pitch differences to distinguish lexical meaning. These tonal differences are typically rather hard to learn for second-language learners, especially when their native language is non-tonal. Previous behavioral and event-related potential (ERP) studies have shown that native speakers of English are sensitive to the onset frequency of the syllables when perceiving (Thai) tones, but less so after training; native speakers of Chinese are more sensitive to changes in pitch contour (Kaan, Barkley, Bao, & Wayland, 2008; Gandour & Harshman, 1978). The aim of the present study was to investigate the effects of language background and training on the perception of lexical tones using time/frequency analysis of EEG. Such an analysis may reveal changes in stimulus induced oscillations and changes in connectivity that are not visible in the (time-locked averaged) ERP. Native speakers of Thai, Mandarin Chinese and American English (a non-tone language) were presented with three tokens of the Thai syllable [kha:] pronounced with a mid-level, high-rising or low-falling tone, while watching a video. Low-falling /high-rising tones were either presented as standards or deviants among mid-level tones. EEG was recorded before and after a two-day categorization training on the same stimuli. For the time/frequency analyses, EEG oscillations time-locked to the onset for low-falling and high-rising deviants and standard, using complex demodulation on frequencies between 1 and 30 Hz. (Regan, 1989). Results showed effects of language background and training. Chinese speakers showed weaker alpha-activity (8-12Hz) between 25 and 250 ms after stimulus onset compared with the English and Thai speakers [$F(2,25)=3.67$, $p=.04$]. A decrease in alpha has typically been associated with an increase in cognitive activity. The weaker alpha for the Chinese speakers suggests that they suffer from interference of their native tone system, and process the Thai sounds less efficiently than native speakers of English or Thai. Overall, theta-activation (4-7Hz) became smaller after training [$F(1,25)=4.31$, $p=.048$], especially for the deviants [$F(1,25)=12.93$, $p=.001$]. A decrease in theta after training suggests that all language groups process the stimuli less attentively. The English speakers showed a stronger theta-activity compared with the Thai and Chinese, especially in the low-falling condition before training [pre/post training \times high/low \times language, $F(2,25)=4.34$, $p=.024$]. This may indicate that the low-falling stimuli are more salient to the English participants. This corresponds to finding that the English speakers showed a larger mismatch negativity in the ERPs to the low-falling deviants compared to the Chinese and Thai, before training (Kaan et al., 2008). Results from the time/frequency analysis therefore both confirm and complement previous ERP findings. Additional analyses are currently carried out investigating changes in connectivity as a function of language background and training.

15. From tones to vowels: a neurophysiological investigation of sine and formant dyads. M. Shvartsman (1), E. Bergelson (2), W. Iidsardi (3). (1) *University of Michigan, Ann Arbor, US.* (2) *University of Pennsylvania, Philadelphia, US.* (3) *University of Maryland, College Park, US.*

While there is a growing literature on neurophysiological responses to simple auditory stimuli (e.g. [1]) and more complex auditory events (e.g. [2,3]), little work has been done to address the question of when and how information from concurrent auditory events is combined, and what the neurophysiological signatures of such processes are ([4]). In the present study we used magnetoencephalography (MEG) to compare the electrophysiological responses to two-tone pairs of sine waves (sine-dyads) with responses from the same pairs of frequencies embedded as F1 and F2 of synthesized vowels (formant-dyads) (see table below). We examined the M100 response to these dyad types using the oddball paradigm.

Condition	Sound 1	Sound 2
Condition 1	523Hz & 1046Hz (sine-dyads)	523Hz & 987Hz (sine-dyads)
Condition 2	523Hz & 1046Hz as F1 & 523Hz & 987Hz as F1 & (formant-dyads) F2 of synthetic vowel	sinusoids (octave) sinusoids (major 7th) F2 of synthetic vowel

The formant-dyads were synthesized with KLSyn (Sensimetrics Inc.) and low-pass filtered at 3000Hz to remove the third and higher formants; both synthesized vowels are perceived as open back vowels, [ɔ]. Crucially, while the formant-dyads do contain additional acoustic information in their fine harmonic structure as compared to the sine-dyads, both dyad sets have a sound component varying between 1046 and 987 Hz. Therefore any difference in mismatch responses must be a result of other information such as the cognitive categorization of the sounds in a particular condition. In each condition, subjects ($n=10$) heard both dyads as standard and deviant. Between-subjects ANOVAs were run with dependent measures deviant M100 amplitude, standard M100 amplitude, and amplitude difference; factors were dyad type (formant-/sine-) and mismatch presentation direction (i.e. which order dyads were heard). Since there was no effect of direction and no interaction between condition and direction, further analyses collapsed across this factor. The ANOVA revealed an effect of dyad type on amplitude difference in both hemispheres ($p<0.003$) and on deviant amplitude in the left hemisphere ($p<0.03$). There was a marginal effect of dyad type on deviant amplitude ($p<0.1$) in the right hemisphere, and no effect on standard amplitude. Based on this data, we conclude that early auditory responses, as indexed by the M100, are modulated by expectations based on cognitive classification as speech or tone as well as by the stimulus's acoustic characteristics. We cautiously suggest that this expectation may rely on similar abstract information to that used by processes of conscious discrimination. To examine this claim, we are currently testing an additional set of conditions where both the sine-dyad and formant-dyad pairs correspond to category differences in music and vowels, respectively.

[1] Jenkins, J. & Poeppel, D. 2007. The analysis of loudness in simple and complex sinusoidal tones: MEG evidence from human auditory cortex. SFN Annual Mtg. San Diego, CA. [2] Krumhansl CL. (2005). *J. New Music Res.* 33: 253-268. [3] Gage, N., Poeppel, D., Roberts, T.P.L., Hickok, G. (1998). *Brain Res* 814: 236-

239. [4] Bergelson, E, Idsardi, W. (2009). *NeuroReport*. 20(3):239-244. [5] Jacobsen, T. (2004). *Neurosci Letters* 362: 204-208. [6] Jacobsen, T., Schröger, E., Sussman, E. (2004). *Cog Brain Res* 20:473-479.

16. Brain-based modelling and neurophysiological investigations of language and attention interactions. *M. Garagnani, Y. Shtyrov, F. Pulvermüller. MRC - Cognition and Brain Sciences Unit, Cambridge, U.K.*

We applied neuroanatomically and neurobiologically grounded computational modeling in conjunction with magnetoencephalography (MEG) experimental methods to address the long-standing debate on how linguistic knowledge is represented in the human brain. Recent simulations obtained with a realistic neural-network model of the left perisylvian cortex suggest that synaptic plasticity mechanisms of long-term potentiation (LTP) and depression (LTD) can lead to the emergence of cortical representations for words consisting of strongly connected circuits that are both distributed and functionally discrete. Such a model replicates, explains and reconciles existing divergent patterns of neurophysiological data (N400 and mismatch negativity) and allows us to make testable predictions about the brain responses to words and pseudowords under different degrees of attention. In particular, the simulation results predicted that: (I) If ample attentional resources are made available to linguistic processes, the brain responses to pseudowords should be larger than those to words (as typically observed in the N400 pattern – see Figure 1, panels (A),(C)), whereas if attentional resources are scarce, the opposite pattern (words >pseudowords, as reported in mismatch negativity experiments – see Fig. 1, panels (B),(D)) should emerge; (II) Neurophysiological responses to familiar words should not be significantly modulated by the availability of attentional resources, whereas responses to unfamiliar, “unrepresented” linguistic items (pseudowords) should show strong attention dependence. To test the model's predictions, we carried out a novel MEG experiment to investigate the processing of linguistic input under different amounts of available attentional resources. Subjects were presented simultaneously with auditory (spoken familiar words and matched unfamiliar pseudowords) and visual (a silent film) stimuli; the same stimuli were presented in two different sessions and attention was manipulated across them. In the “Attend” session, subjects were instructed to ignore the video, focus completely on the sounds, and respond to specific auditory targets. In the “Ignore” session, they were told to ignore the sounds and focus their attention on the silent film; they were made aware that at the end of the session they would be given a questionnaire on the contents of the film. We found that: (I) when subjects attended the auditory stimuli, the brain response to pseudowords was larger than that to words (as in the N400 pattern), whereas when attention was directed away from the linguistic input, the opposite pattern emerged (words >pseudowords). In addition: (II) while the magnetic mismatch negativity (MMN) response to words did not significantly change across sessions (indicating that the cortical circuits underlying word representations are relatively immune to changes in attention levels), the MMN to pseudowords exhibited profound variability: the amplitude was enhanced above that to words in the Attend condition, and reduced below it in the Ignore condition. These results confirm the model's predictions and provide evidence in support of the hypothesis that words are represented in the brain as functionally discrete, distributed action-perception circuits.

17. Compensatory networks engaged during simulated deficits of speech processing. *J.E. Warren (1) S.L.E. Brownsett (2) F. Geranmayeh (3) J.D. Warren (4) R.J.S Wise(5). (1) Imperial College London and MRC Clinical Sciences Centre, London, UK (2) Imperial College London and MRC Clinical Sciences Centre, London, UK (3) Imperial College London and MRC Clinical Sciences Centre, London, UK (4) University College London, London, UK (5) Imperial College London and MRC Clinical Sciences Centre, London, UK*

The recruitment of compensatory neural systems is assumed to be a critical mechanism for ameliorating language deficits after focal brain lesions. However the organization of these compensatory neural resources remains poorly understood. In this functional MRI study, we investigated the compensatory neural systems engaged by the normal brain during spoken language processing under conditions intended to simulate deficits of speech comprehension and self-monitoring of speech output. To establish normal substrates of speech comprehension and repetition, healthy volunteers heard and repeated natural sentences in consecutive trials of a sparse-sampling paradigm. To investigate compensatory neural activity associated with simulated impairment of receptive speech processing, subjects attempted to comprehend and repeat low-intelligibility acoustically-degraded sentences. Repetition trials were randomly masked with white noise to examine the effects of impeding auditory feedback during articulation. Group analysis demonstrated that listening to natural speech activated a distributed bilateral frontotemporal network, including activity in motor and premotor areas consistent with preparation for subsequent repetition. Overt repetition of natural sentences activated a similar bilateral frontotemporal network, with significantly greater activation in primary motor and premotor regions. Listening to low-intelligibility degraded speech produced significantly greater activity at strategic sites within the network engaged by natural speech, including bilateral supplementary motor area, caudate nuclei and left inferior frontal gyrus. However, overt repetition of degraded speech was associated with increased activity in regions outside the network activated by natural speech, including lateral and medial prefrontal cortex and angular gyrus regions associated with cognitive effort, monitoring and semantic processing. In contrast, impedance of auditory feedback during repetition was associated with increased activity in brainstem auditory pathways and planum temporale bilaterally. This study demonstrates that simulated speech-processing deficits engage multiple compensatory mechanisms, including upregulation of activity within normal speech-processing networks, recruitment of additional cognitive systems beyond language cortex, and “bottom-up” augmentation of perceptual input. The extent to which focal lesions involve these compensatory systems as well as primary language substrates may be a key determinant of both the severity of aphasic deficits and their potential for recovery.

18. Linking whole brain activation patterns to behaviour: examples from language and math. R. D. S. Raizada (1), F. M. Tsao (2), H. M. Liu (3), I. D. Holloway (4), D. Ansari (4), and P. K. Kuhl (5). (1) Neukom Institute for Computational Science, HB 6255, Dartmouth College, Hanover NH 03755. (2) Dept. of Psychology, National Taiwan University, Taipei 10617, Taiwan. (3) Dept. of Special Education, National Taiwan Normal University, Taipei 10644, Taiwan. (4) Dept. of Psychology, Univ. of Western Ontario, London, ON N6G 2K3, Canada. (5) Inst. for Learning & Brain Sciences, Univ. of Washington, Box 357988, Seattle WA 98195.

Recent studies show that distributed fMRI patterns can predict individual differences in behaviour. However, there are many possible choices when performing pattern-analysis and voxel-selection, with each choice potentially biasing any correlations that emerge. A related concern stems from using specific regions-of-interest (ROIs) when seeking brain-behaviour correlations. If the criterion used to define a given ROI is the same as the one being tested for in the data extracted from that ROI, then the resulting correlation test may be biased or even wholly invalid (Vul et al., 2009; Kriegeskorte et al., 2009). In the present study we show that, on the contrary, a simple classifier applied to the whole brain at once can indeed find strong brain-behaviour correlations, across two distinct data sets using very different behavioural tasks. This whole-brain classifier uses no voxel selection, and just plain linear regression. This linear regression had the category labels +1 and -1 as the desired outputs. The resulting model classifies an input as category +1 or -1 according to whether its output is greater than or less than zero. We applied this whole-brain classifier to data from our recent study of how Japanese and English subjects perceive the syllables /ra/ and /la/, in which we showed that the degree to which a classifier could separate the neural patterns elicited by those sounds predicted how well people could behaviourally tell the sounds apart, not only across groups but also across individuals (Raizada et al., *Cerebral Cortex*, 2009). The results of applying the whole-brain test to the /ra/-/la/ study are remarkably similar to those obtained in that study, except that the present test is across the whole-brain, whereas that study used a small Heschl's gyrus ROI and an SVM classifier. In order to test the generalisability of this finding, we also applied the same technique to data relating fMRI activation on a non-symbolic numerical "distance effect" task to behavioural scores on standardised tests of arithmetic and language. We found a similar result in this distance-effect data: the separability between neural patterns elicited by large-distance pairs and small-distance pairs was positively correlated with subjects' scores on the arithmetic tests. However, this pattern separability measure was calculated not from a parietal cortex ROI, but from the whole brain at once. With interest in pattern-based fMRI analyses rapidly growing, and with a proliferating number of different methods being used, the approach proposed here may offer a common point of comparison: a test for brain-behaviour correlations which is fast, simple and rigorous.

19. Language-Specific Phonological Knowledge Modulates Early Auditory MEG Responses to Transient Consonants. J. Riley (1), A. Rhone (1), and B. Dillon (1) (1) University of Maryland - College Park, College Park, US.

Previous work has demonstrated the sensitivity of the M50 (Tavabi et al. 2007) and the M100 (Obleser et al. 2006) responses in magnetoencephalography (MEG) to the linguistic features (specifically place) of syllable onsets independently of low-level acoustic variations between individual tokens of syllables. Such work provides evidence for the importance of distinctive features in speech perception, as featural information is apparently extracted from the signal and encoded quite rapidly by the auditory system. However, previous studies have examined only one category of distinctive feature (place of articulation) in one language and thus it is crucial to investigate whether rapid extraction and encoding happens for other distinctive features found cross-linguistically. The present study examines the early auditory responses of English and Amharic speakers to the first 50 milliseconds of plain and ejective consonants with MEG. Amharic is a Semitic language of Ethiopia that distinguishes between plain and ejective consonants with otherwise similar voicing, place and manner of articulation, such that /t/ and /t'/ are different phonemes (Titov 1976). Phonetic investigation has suggested that the acoustic cues to ejectiveness are a difference in amplitude between the bursts of the plain and ejective sounds and a glottal lag following burst offset in ejectives (Demolin 2001). Since our plain and ejective stimuli are amplitude-matched, this glottal lag is the only available, phonetically-motivated cue. The first 50 milliseconds of /Ca/ syllables with plain and ejective consonants at velar [ka, k'a] and labial [pa, p'a] places of articulation produced by native speakers of Amharic were extracted and played to native speakers of English and of Amharic during recording in a 150-channel MEG scanner [axial gradiometer, KIT, Japan], while subjects completed a distractor tone-monitoring task. These transient consonant onsets are distinguished by phonological category for Amharic speakers but not for English speakers. Therefore, by hypothesis, if early auditory responses make use of contrastive distinctive feature information, the early auditory responses of Amharic and English speakers should differ significantly. Our results confirm our hypothesis by demonstrating that the M50 and M100 responses have a substantially different time course for speakers of English and speakers of Amharic based on the place of articulation of the stimulus presented. Figure 1. Average MEG response to velar (black) and labial (red) consonants for Amharic and English speakers. In other words, the amplitudes M50 and M100 components for each group show effects of place of articulation, but these effects emerge at different times depending on the native language of the listener. Early auditory responses to plain versus ejective consonants also differ based on language group. These differences are a natural consequence of the differing phonological systems of English and Amharic, and the early emergence of these differences reflects early top-down influence of phonological knowledge at the earliest stages of cortical speech processing. This is the first demonstration of which we are aware of the effects of language-specific phonological knowledge in speech processing at the 50 or 100-millisecond stage. References: Tavabi K, Obleser J, Dobel C, Pantev C. (2007) Auditory evoked fields differentially encode speech features: an MEG investigation of the P50m and N100m time

courses during syllable processing. *The European Journal of Neuroscience* 25(10):3155-62. Obleser J, Scott S, Eulitz, C. (2006) Now you hear it, now you don't: transient traces of consonants and their non-speech analogues in the human brain. *Cerebral Cortex* 16(8): 1069-1076. Demolin, Didier. (2001) Acoustic and aerodynamic characteristics of ejectives in Amharic. *Journal of the Acoustical Society of America*. 115(5): 2610-2610. Titov, EG. (1976) *The Modern Amharic Language*. Nauka Publishing House, Central Department of Oriental Literature: Moscow.

20. The fragment priming paradigm: Insights into lexical access. *M. Scharinger (1), V. Felder (2), and C. Eulitz (2).* (1) *University of Maryland, College Park, US* (2) *University of Konstanz, Germany*

Research in speech perception has repeatedly shown that lexical access takes place as early as 200 ms after word onset. Further, initial fragments, i.e. word beginnings, were shown to successfully activate the meaning of the word they were taken from, as well as of words semantically related to them (Marslen-Wilson & Zwitserlood, 1989). The research of Friedrich and colleagues has identified an ERP component which is sensitive to the activation of words by their initial fragments (Friedrich, Kotz, Friederici, & Gunter, 2004). Compared to a control condition, they found a less positive going response at around 350 ms after word onset when words were preceded by their initial fragments (first syllables): For instance, cross-modal prime-target pairs in German such as Ma >(auditory) Makel (visual, 'flaw') produced reliable P350 priming effects. In this paper, we were interested whether we could replicate this effect in a cross-modal fragment priming experiment where the relation between primes and targets was not only based on formal overlaps but also on meaning-based relations. Thus, we additionally included a condition where the prime fragment was taken from a word semantically related to the target (e.g. Fe-Makel 'flaw', Fe- from Fehler 'error'). Our main objective was to test whether we would see a semantic fragment priming effect in the P350 time window, or possibly before or after. An initial behavioral priming experiment with 45 subjects yielded robust target facilitation in both the identity (i.e. Ma-Makel) and the semantic (i.e. Fe-Makel) condition. This is in line with earlier findings. The ERP study with 16 participants, in which we continuously recorded the brain potential from 64 electrode positions during the priming task, showed several noteworthy effects. First, we could replicate the P350 priming effect for the identity condition. Responses to words like Makel showed a less positive going waveform if preceded by Ma, than if preceded by an unrelated fragment. In contrast, there was no such effect for the semantic condition. Neither was there any N400 modulation. However, both the identity and the semantic condition produced more negative going peaks in the N170 time window. We interpret these findings as follows: The P350 priming effect in the identity condition replicated early findings and appeared to reflect form-based similarities between the prime and the target. Crucially, the first syllable of the target word was sufficient to initiate facilitated target processing. The absence of this effect for the semantic condition suggests that the P350 modulation is mainly elicited by formal overlaps. The lack of a N400 modulation can be attributed to our relatively long SOA, which possibly weakened an automatic spreading of meaning-based information, and to our prime-presentation of only first syllable fragments (cf. Holcomb & Grainger, 2009). Finally, the N170 modulation obviously reflected an early semantic context effect. Identity as well as semantic fragments accessed their full word forms and thereby pre-activated these forms as well as semantically related words. The early latency of this effect is in line with other studies on speech perception (Pulvermüller, Assodollahi, & Elbert, 2001).

21. PLACES of good MANNERS: Early MEG differences of fronted segments. *J. Riley (1), M. Scharinger (1), J. Merrickel (2), and W. Idsardi (1).* (1) *University of Maryland, College Park, US* (2) *University of Rochester*

Models of speech perception can be broadly classified into two categories: In one, the emphasis is on acoustic-phonetic details (Goldinger & Azuma, 2003), in the other, the focus is on abstract phonological categories (Phillips et al., 2000). We assume that both kinds of information play a crucial, interactive role during speech perception. In this paper, we explore when in the course of spoken word perception phonological specifications become available for processing. Following traditional phonological accounts, we distinguish between place and manner of articulation and investigate potential processing differences between them. Labial and palato-alveolar fricatives and glides (e.g. /j, w, ʒ, v/) were used word medially in natural sequences of aCa (where C=consonant) and tested in a standard-deviant design using MEG (Phillips et al., 2000). The Mismatch Field (MMF) elicited by place of articulation differences in the fricatives and glides were compared. MEG responses were localized in the left hemisphere via a prior tone perception test. The results showed that at several latencies, magnetic field amplitudes were higher for the labial than for the palato-alveolar fricatives. These differences caused a significant interaction of place and position (standard, deviant) in the MMF latency at around 150-200 ms after consonant onset. Remarkably, the earliest differences could be seen at the M50 and M100 latencies of the initial vowel, where the labials also yielded higher field amplitudes (Figure 1). These differences correlated with co-articulatory effects of the consonants onto the preceding vowel. In particular, the labial consonants caused a significant fronting (as measured in F2 values across our stimuli). The results of the second study with aja as standards and awa as deviants resembled the results of the first study. The labial glide produced higher magnetic field amplitudes than the palatal glide as early as 50 ms after the onset of the initial vowel. The MMF elicited by the labial glide deviant was lower in amplitude than that of the /v/. This is expected as the labial glide is, in English, produced at multiple places of articulation (i.e. labial with velar constriction). We interpret these findings as reflecting an asymmetry in place of articulation. The automatic change detection response of the brain is more sensitive to changes from a mid-position to a front position than vice versa. These results are consistent with the findings of Obleser and colleagues (Obleser, Scott, & Eulitz, 2006) and also fit in the asymmetry assumptions by Lahiri & Reetz, 2002, although it seems that depending on the processing level, asymmetries are not always brought about by underspecification. We leave to further investigation how other

languages differentially specify phonological features (i.e. what counts as “front”) as well as whether the frequency distributions of the consonants might explain our results. The view that spoken word processing involves multiple levels of representations is further supported by our findings. Sounds are first evaluated on a phonetic level, which deals with low-level acoustic detail (e.g. co-articulation), and are then passed onto a phonological level, which is abstract in nature and uses categories such as “front” or “back”.

22. ERP evidence for laryngeal underspecification in English. A. Hestvik (1) K. Durvasula (1,2) E. Bradley (1) C. Bradley (1). (1) University of Delaware (2) Michigan State University.

The objective of the study was to examine whether there is neurobiological evidence in favor of the view that there is laryngeal under-specification in English. Voiceless stops in English are underlyingly specified for the feature [spread glottis], while voiced stops are underlyingly underspecified for laryngeal features (Iverson & Salmons, 1995). Eulitz & Lahiri (2004), using German vowels, showed that a less (featurally-) specified deviant produced a mismatch to a more (featurally-)specified standard, but a more (featurally-) specified deviant did not produce a mismatch to a less (featurally-)specified standard. The assumption is that when tokens are varied within category in MMN paradigms, this causes the standard to be represented as a phoneme rather than a phonetic/acoustic representation. Given the laryngeal underspecification theory of stops in English, this predicts that standard t's are followed by a deviant 'd' should generate a mismatch, because the d's phonetic representation of voicing is the opposite of the specified features for a phonologically represented /t/. On the other hand, when standard d's is followed by deviant t's, there will be no mismatch, because the phonetic representation of [t] is compared to a phonological representation of /d/, which has no specification for voicing. We tested this prediction in a mismatch negativity study (N=23) utilizing the modified oddball paradigm of Phillips et al. (2000). Two blocks each with 700 standards and 100 deviants were presented in pseudo-randomized order. 15 subjects heard [t]'s as a standard in the first block and 9 subjects heard [d]'s as a standard in the first block (we have since added substantial number of subjects to balance this for N and gender). An additional target detection task of a different stimulus was interspersed among the trials (unrelated to the current experiment). EEG was acquired with a 128 channel EGI system. The MMN was measured at FCz (EGI electrode E6, cf. Figure) after localizing the effect using spatial PCA, and calculated within category, i.e. deviant 'd' compared to standard 'd', and vice versa for 't'. The difference in MMN amplitude was significantly greater for 'd' than for 't' ($F(1,21) = 3.01, p < .05$ one-tailed). This effect became highly significant once block order was controlled for: hearing 'd' as a deviant in the first block yielded significantly greater MMN than hearing 't' as deviant in the first block ($F(1,21)=19, p < .001$). We also observed a late discriminative negativity (LDN) to 'd' as deviant, which was absent for 't' as deviant. The LDN is a large negative going wave at anterior electrode sites to the deviant stimulus, in the 300-500ms range. The functional significance of LDN is not certain (Ceponien et al., 2004), but is assumed to be triggered when a salient deviant stimulus reaches the level of attention (Shestakova et al., 2003). Together, the MMN data and the LDN data bear out the prediction that there is an asymmetry between /t/ and /d/ in terms of the magnitude of the brain response in an MMN-experiment. This provides neurophysiological evidence for underspecification theory.

23. Audiovisual speech perception and eye movements in the Asperger syndrome. S.Saalasti (1), J.Kätsyri (2), K. Tiippana (3), M. Laine-Hernandez (4), L. von Wendt (5), and M. Sams (6). (1) Department of Speech Sciences, University of Helsinki, Helsinki, Finland (2) Center for Knowledge and Innovation Research (CKIR), Helsinki School of Economics, Finland (3) Department of Psychology, University of Helsinki, Helsinki, Finland (4) Department of Media Technology, Helsinki University of Technology, Espoo, Finland (5) Department of Pediatric and Adolescent Medicine, Helsinki University Central Hospital, Helsinki, Finland (6) Department of Biomedical Engineering and Computational Science, Helsinki University of Technology, Espoo, Finland.

Asperger syndrome (AS) is a lifelong developmental disorder of social interaction and behaviour. It belongs to the continuum of autism spectrum disorders (ASD). Individuals with ASD are reported to have difficulties in processing uni- and multisensory information, but research especially on the latter issue is still sparse. Speech is a good example of a multisensory process since articulation produces both audible speech sounds and visible gestures on the talking face. Previous studies have shown that children and adolescents with ASD perceive audiovisual speech differently from neurotypical controls. The purpose of this study was to find out whether adult individuals with AS show similar reduced influence of visual articulation, and to track their eye movement patterns when observing visual or audiovisual speech since atypical use of eye gaze is a feature in ASD. We studied audiovisual speech perception by utilising the McGurk effect in which viewing conflicting visual articulation alters perception of heard speech. Furthermore, we registered eye gaze during speech perception (recognition of consonants /k/, /p/, /t/) in 16 adult individuals with AS. Results were compared with age, gender and IQ (WAIS-R) matched control group. Our results show that individuals with AS were less influenced by visual speech in the audiovisual condition, even though they recognized auditory and visual speech alone nearly as well as control participants. Clear differences between groups were evident in responses for audiovisual stimulus A/p+/V/k/. Control participants showed strong visual influence and answered dominantly by the visual component /k/ (95% of responses). In contrast, the responses in the AS group were distributed almost equally between the response categories /k/ (49%) and /t/ (46%). The proportion of /k/ responses was significantly lower [$F(1, 30) = 16.67, p < .001$] and the proportion of /t/ responses significantly higher [$F(1,30)= 19,27, p < .001$] in the group of AS participants. However, there was variability in the responses of the AS group: half of the participants responded like control participants (/k/ according to the visual component), but 7 subjects always perceived the stimuli as /t/. Both groups had the highest number and longest total duration of eye fixations on the mouth area of the talking face. However, the AS

group fixated less on the mouth during audiovisual speech than when visual speech was presented alone. The analysis revealed a significant interaction of modality and group [$F(1,28)=6.52, p < .02$]. These results provide evidence that processing of audiovisual speech is different in adult individuals with AS than in their control participants, giving support to the hypothesis that integration of cross-modal sensory signals may be affected in the ASD. Although the eye gaze patterns of individuals with AS were different from those of controls specifically in the audiovisual condition, these results are unlikely to explain the differences in perception. Looking away from the mouth may reduce visual influence but is unlikely to account for the large perceptual effect. The averted gaze from mouth area may reflect avoiding complex, multisensory perceptual information.

24. Audiovisual speech perception and visual spatial attention in the Asperger syndrome. *K. Tiippana (1), S. Saalasti (2), J. Kätsyri (3), L. von Wendt (4), and M. Sams (5).* (1) Helsinki University of Technology, Espoo, Finland. Currently at: University of Helsinki, Helsinki, Finland. (2) University of Helsinki, Helsinki, Finland. (3) Helsinki University of Technology, Espoo, Finland. Currently at: Helsinki School of Economics, Helsinki, Finland (4) HUCH Hospital of Gynecology and Pediatrics, Helsinki, Finland. (5) Helsinki University of Technology, Espoo, Finland.

Asperger syndrome (AS) is a lifelong developmental disorder of social interaction and behaviour belonging to the continuum of autism spectrum disorders (ASD). Individuals with ASD are reported to have difficulties in integrating sensory information, as well as in selective attention. We studied the interaction between audiovisual speech perception and visual spatial selective attention in 16 adult individuals with AS, and compared the results with age, gender and IQ-matched control participants. To assess audiovisual integration, we utilised the McGurk effect in which conflicting visual articulation alters perception of heard speech. To test the functioning of visual selective attention, we presented two talking faces side by side, and instructed participants to covertly attend to one face and to ignore the other face, while fixating a central cross between them. Central fixation was monitored with an eye tracker, so that the faces remained equidistant in perifoveal visual field to the left and right of fixation. In a comparison condition, only one face was presented in an otherwise identical set-up. Recognition of consonants /k/, /p/ and /t/ was tested for auditory, visual and audiovisual speech. Auditory speech was correctly categorized in both groups. Also, both groups recognized visual speech very accurately when only one face was presented. When two faces were presented, K-responses to attended visual /k/ (in the presence of to-be-ignored face articulating /t/) were still very high, but decreased slightly. This fall was accompanied by a corresponding increase in T-responses, similarly in both groups. This suggests that visual attentional selection between two faces was equally successful in both groups, even though the to-be-ignored face interfered slightly with the visual speechreading of the attended face. In audiovisual conditions, both groups exhibited strong visual influence on auditory perception (i.e. a strong McGurk effect), indicated by a drastic drop in the percentage of auditory responses. The most marked difference between the groups was that when auditory /p/ was presented with a single face articulating visual /k/, the individuals with AS responded largely hearing T, meanwhile the controls reported hearing almost exclusively K. When auditory /p/ was presented with two faces, participants' response patterns were similar to when only one face was presented, except that there was an increase in responses corresponding to the non-attended face for both groups. That is, when visual /k/ was attended, there was a small increase in T-responses in the two-face condition, compared with the one-face condition. These findings suggest that individuals with AS integrate multisensory signals somewhat differently from the control participants, while their ability to guide visual spatial attention seems intact under these conditions. The underlying reason for the difference in audiovisual speech perception between groups is thus unlikely to be related to attentional factors. It may be that one contributing factor to the difficulties in face-to-face communication experienced by individuals with AS may be related to an aberration in integrating information from different sensory modalities.

25. Rapid temporal processing in the Left Hemisphere? A case study of unilateral Pure Word Deafness. *L.R. Slevc (1), A.C. Hamilton (1), M.F. Joanisse (2), and R.C. Martin (1)* (1) Rice University, Houston, TX, US (2) University of Western Ontario, London, Ontario, Canada.

Pure word deafness (PWD) is characterized by severely impaired speech perception despite good hearing ability and preserved functioning in other language domains (i.e., reading, writing and speaking). Despite its rarity, PWD has attracted considerable attention because of its specificity to speech sounds. 'Pure' cases of PWD show dissociations not only between speech perception and other types of linguistic processing but also between perception of speech stimuli and other complex auditory stimuli. The case reported here shows exactly this pattern: severely impaired speech perception despite relatively preserved reading, writing and speaking ability, as well as preserved perception of complex environmental sounds (Bozeat et al., 2000) and musical pitch. Although PWD typically results from bilateral damage to the posterior superior temporal lobes, or more rarely from damage to the left superior temporal lobe combined with damage to inter-hemispheric connections, this patient has only unilateral left temporal and parietal lobe damage, including superior temporal gyrus, supramarginal gyrus, and angular gyrus. Not only does he have an intact right hemisphere, but he also has preserved white matter tracts connecting the two hemispheres as shown by diffusion tensor imaging. This pattern suggests a crucial role played by the left superior temporal regions in speech perception, perhaps reflecting a specialization for the processing of rapid temporal aspects of the speech signal (cf. Stefanatos, Gershkoff, & Madigan, 2005). To test this account, this patient's ability to discriminate between stimuli differing in rapid temporal vs. spectral dimensions was assessed with synthesized stimuli (modeled after Joanisse & Gati, 2003). Temporal discrimination ability was assessed with both synthesized consonants (speech condition) and closely matched sinewave sweeps (non-speech condition), with fast (20 ms), medium (40 ms), or slow (60 ms) formant transition times. Spectral discrimination ability was assessed with synthesized vowels (speech condition) and

sinewaves matched to the vowel formant pitch differences (non-speech condition). As predicted, the patient showed worse processing of rapid temporal than spectral stimuli in both speech and non-speech stimuli, especially for the fastest transitions. However, the patient also showed considerably worse processing of speech than non-speech stimuli, a pattern true both for temporal contrasts (consonants & sinewave sweeps) as well as for spectral contrasts (vowels and sinewave pitches). These data thus only partially support theories of a left-hemispheric specialization for rapid temporal processing, and suggest a crucial role of the left-hemisphere in processing other non-temporal aspects of speech complexity. Bozeat, S., Lamdon Ralph, M.A., Patterson, K., Garrard, P., & Hodges, J.R. (2000). Non-verbal semantic impairment in semantic dementia. *Neuropsychologia*, 38, 1207-1215. Joanisse, M.F. & Gati, J.S. (2003). Overlapping neural regions for processing rapid temporal cues in speech and nonspeech signals. *NeuroImage*, 19, 64-79. Stefanatos, G.A., Gershkoff, A., & Madigan, S. (2005). On pure word deafness, temporal processing, and the left hemisphere. *Journal of the International Neuropsychological Society*, 11, 456-470.

26. Contributions of sensory and linguistic information to audiovisual sentence comprehension: an fMRI study using a cochlear implant simulation. C. McGettigan (1), A. Faulkner (2), I. Altarelli (2), J. Obleser (3), and S.K. Scott (1). (1) *Institute of Cognitive Neuroscience, University College London, London, UK* (2) *Department of Speech, Hearing and Phonetic Sciences, University College London, London, UK* (3) *Max Planck Institute for Human Cognitive and Brain Sciences, Leipzig, Germany*.

It has been demonstrated many times that speech comprehension can be enhanced by the addition of information from various sources: improved clarity in the auditory domain, the presence of a concurrently moving face, greater linguistic predictability in the spoken material. There is a well-established positive relationship between the amount of spectral detail in noise-vocoded (NV) speech and its intelligibility, which is borne out neurally in bilateral superior temporal cortex (Scott et al., 2002). Two recent neuroimaging studies have investigated how other factors interact with this relationship: in fMRI, Obleser et al. (2007) found recruitment of a fronto-parietal network for sentences of higher semantic predictability under conditions of intermediate acoustic intelligibility, while in PET Scott et al. (in prep) found that the visual clarity of an accompanying face enhanced auditory responses in anterior STS bilaterally. The present study investigated three factors – Auditory Clarity (through noise-vocoding), Visual Clarity (via Gaussian blurring of a moving face) and Semantic Predictability – in an audiovisual sentence comprehension task in fMRI. We found strong bilateral superior temporal, inferior frontal and premotor activity in response to increasing auditory intelligibility. For clearer faces, there was increased activity in bilateral occipital cortex and posterior STS, left anterior STS and right amygdala, as found in Scott et al. (in prep). Similarly to Obleser et al. (2007), we also identified increased fronto-parietal activity for higher-predictability sentences, however with additional peaks in bilateral posterior STS. In our study, this predictability effect was seen only for sentences with intermediate auditory intelligibility and greater facial clarity, reflecting a level of behavioural sentence recognition that was good but well below ceiling. The posterior temporal activations for the effects of blurring and predictability overlapped, suggesting, as indicated by the predictability finding, a 3-way interaction of all the factors at this location. In conclusion, we have shown separable contributions of sensory and linguistic factors to NV speech comprehension in a single group of participants. Beyond this, we identify the posterior STS as a potential site for multimodal integration of multiple cues during a difficult speech comprehension task.

27. How are ‘Barack Obama’ and ‘president elect’ differentially stored in the brain? An ERP investigation on the processing of proper and common name pairs. A.M. Proverbio (1), S. Mariani (1), A. Zani (2), and R. Adomi (1). (1) *University of Milano-Bicocca, Milan, Italy* (2) *National Research Council, Milan, Italy*

One of the most intensely debated issues in the cognitive neuroscience of language is whether distinct semantic domains are differentially represented in the brain. Clinical studies have described several anomalous dissociations with no clear neuroanatomical correlate. Neuroimaging and ERP studies have shown that memory retrieval is more demanding for proper than common names in that the former are purely arbitrary referential expressions. In this study a semantic relatedness paradigm was devised to investigate neural processing of proper and common names without engaging memory retrieval processes. Seven hundred and eighty proper and common names (arranged in pairs of Italian nouns/adjectives and the first/last names of well known persons) were presented to 16 right-handed University students. The items in half the pairs were semantically related (e.g. “Woody Allen” or “social security”), while in the other half they were not (e.g., “Sigmund Parodi” or “judicial cream”). All items were balanced (within and between classes) for length, written frequency of use, familiarity and semantic relatedness. Imageability and cloze probability were also measured for each word pair. Participants were asked to decide about the semantic relatedness of the two items in a pair by pressing one of two buttons. RTs were faster to proper than common name pairs, while N400 latency was earlier to unrelated proper names. N400 amplitude was larger to common names. This pattern of results suggests that this specific task, not explicitly involving memory recall, was more demanding for common names, since cloze probability was greater for proper name pairs. P400 was much larger to related proper name pairs (recognized famous persons) than unknown persons or recognized things. The LORETA neural generators for the former effect included the left fusiform gyrus (BA20, 37), the right medial temporal gyrus (BA21), limbic and parahippocampal regions, and left inferior parietal (BA40) and inferior frontal (BA6) areas, which are thought to be involved in the conjoint processing a familiar face with the relevant episodic information. The neural generators of N400 to unrelated items investigated using a LORETA inverse solution did not differ as functions of lexical class, thus suggesting that proper and common names are not treated differently as belonging to different grammatical classes. Supported by 2008 FAR grants from MIUR.

Speech production

28. The Larynx Representation of the Human Motor Cortex. S. Brown (1) E. Ngan (2) M. Liotti (3). (1) McMaster University (2) University of British Columbia (3) Simon Fraser University.

The larynx is the major organ of phonation, controlling the pitch of all vocal sounds. The map of the human motor cortex has lacked a representation for the intrinsic musculature of the larynx ever since the electrical-stimulation studies of Penfield and colleagues in the 1930's and 40's. My colleagues and I sought to localize an area controlling the intrinsic muscles of the larynx by using functional MRI, and to place this area in a somatotopic context. We had subjects perform a series of oral tasks designed to isolate elementary components of phonation and articulation, including vocalization of a vowel, lip movement, and tongue movement. In addition, and for the first time in a neuroimaging experiment, we had subjects perform glottal stops in the absence of vocalizing. The results demonstrated a larynx-specific area in the motor cortex that is activated comparably by vocal and non-vocal laryngeal tasks. Converging evidence suggests that this area is the principal vocal center of the human motor cortex, as demonstrated by our finding that this region is the major site of activation for both oral reading and singing. Finally, the location of this larynx area is strikingly different from that reported in the monkey. Hence, it is likely that the motor cortex has undergone reorganization during hominin evolution, not least for the emergence of vocal learning and the voluntary control of vocalization seen uniquely in humans among primates.

29. Localization of language functions with MEG. M. Pirmoradi (1,2), R. Béland (1), B.A. Bacon (3), M. Robert (1), and M. Lassonde (1,2). (1) University of Montreal, Montreal, Canada (2) Ste-Justine Hospital, Montreal, Canada (3) Bishop's University, Sherbrooke, Canada.

Determining the hemisphere that is dominant for language as well as the localization of this function is imperative in the planning of neurosurgical procedures for epileptic patients. New noninvasive diagnostic techniques are under development because of the risks associated with more invasive techniques. The goal of the present project was to determine the lateralization of language using magnetoencephalography (MEG), a non-invasive technique. In order to do this, 3 tasks were complete in the MEG. A verbal fluency task was used to assess language production, a story listening task allowed to evaluate language comprehension, and a word recognition task was used to look at verbal memory. Activation in the frontal and temporal lobes was found after completion of these tasks in the MEG.

30. Neural systems for perception, production and repetition of spoken pseudo-words: an fMRI study. G. Szenkovits (1), D. Norris (1), M. H. Davis (1). (1) MRC-CBU, Cambridge, UK.

The neural networks underlying speech perception and production have been extensively studied using functional imaging. However, the relationship between these two networks – in particular the proposal that systems involved in speech production are recruited for the perception of speech – remain controversial (i.e. D'Ausilio et al. 2009; Lotto et al. 2009; Papoutsis et al. 2009; Scott et al. 2009;). In the present fMRI study, we investigated basic phonological input (perception) and output (production) processes, and the link between the two during immediate verbal repetition. We used three blocked-design functional Magnetic Resonance Imaging (fMRI) paradigms to assess neural activity during (1) speech perception, (2) speech production, and (3) the link between perception and production under minimal or no memory load conditions. All speech conditions were contrasted with non-speech conditions matched for stimulus and response characteristics. (1) For speech perception we contrasted listening to spoken pseudo-words with acoustically-matched non-speech sounds (speech-envelope and spectrum buzzes created by pulse-train vocoding). The task used was a one-back identity detection with pseudo-words judged phonologically by presenting speech that alternated between a male and a female speaker. (2) The speech production task involved reading single pseudo-words aloud compared to saying "yes" to length matched strings of consonants. (3) For spoken repetition (capturing both speech perception and production), we combined the input and output characteristics of these two paradigms such that subjects repeated aloud spoken pseudo-words, and said "yes" to acoustically matched non-speech buzzes. Results obtained in a group of 25 healthy, right-handed native English speakers highlight largely non-overlapping regions responsible for phonological input and output processes. Speech perception engaged bilateral regions of the Middle Temporal Gyrus (MTG) and in the left Inferior Frontal Gyrus (LIFG), and Inferior Temporal Gyrus (ITG) – this last possibly reflecting orthographic influence on speech perception (i.e. Perre, L., & Ziegler, J. C. 2008). We also saw activation in orbito-frontal and precuneus regions, though this may relate to the greater difficulty of the baseline auditory task. For speech production, we observed extensive activation of bilateral motor/premotor cortex, LIFG, LITG and the cerebellum. In addition a region of the Superior Temporal Gyrus (STG) was activated reflecting responses to heard spoken responses. Although, the repetition task revealed activation that overlapped with networks for both speech perception and production, these commonalities apart, we saw surprisingly little overlap between activation for speech perception and production. Frontal responses during speech perception were largely confined to inferior frontal regions and did not extend into motor regions. Furthermore, while peri-auditory STG regions were activated during speech production, responses did not extend into the MTG regions that showed a speech-specific response during perception. These findings suggest that although links between speech perception and production serve an important function in controlling speech production and during repetition and short-term memory tasks, direct connections between perception and production may not be observed during speech perception tasks.

31. The segregation of lexical access stages using fMRI. S. Abel (1,2), K. Dressel (1,2), C. Weiller (2), W. Huber (1). (1) *Neurolinguistics, Department of Neurology, RWTH Aachen University* (2) *Neurocenter, Department of Neurology, Freiburg University*

Introduction In confrontation naming of healthy subjects, the additional presentation of distractor words influences naming latencies as well as brain activations measured by functional magnetic resonance imaging (fMRI). Naming responses are speeded by (1) associatively-related or (2) phonologically-related words when compared to (3) unrelated words, while they are slowed down by (4) categorically-related words. However, a direct comparison of all four distractor types in a single fMRI-paradigm has not been performed yet, probably due to the findings that optimal stimulus onset asynchronies (SOAs) differ between them. In the present study, we for the first time integrated all four auditorily presented distractor types into one paradigm at an SOA of -200ms, in order to directly compare behavioral and neural interference effects. Main goal was to specifically activate semantic and phonological processing stages. Methods 19 healthy German speakers participated in this study on a 3T Siemens MRI system. We used a T2* EPI sequence (TR 2190ms, TE 30ms, FA 90°) and acquired 36 transversal slices (thickness 3mm). The experiment was conducted in an event-related design with two sessions requiring overt naming with auditory distractors (140 distractor/picture combinations). Each picture to be named was preceded by a word with phonological (P; distractor Karte/card, target Katze/cat) or associative-semantic relation (monkey/banana), a word from the same semantic category (C; lamp/candle), or an unrelated word without any target relation (kiwi/bed). Here we present ANOVAs analyzed with SPM5 for contrasts P>C and C>P, which are presumed to yield activations associated with phonological and lexical-semantic processing, respectively. Contrasts were FDR-corrected, thresholded at $p=.05$ and inclusively masked by the minuend with $p=.05$ uncorrected in order to eliminate deactivations. Results All distractor types influenced response latencies as expected. In decreasing order of latencies, categorical, unrelated, phonological, and associative distractors interfered with naming. Contrast P>C (see Figure, red) evoked activations in bilateral superior/middle temporal gyrus (STG/MTG) extending to bilateral postcentral gyrus, insula, supramarginal gyrus (SMG), inferior parietal lobule (BA 40), as well as left inferior frontal gyrus (IFG; BA 44). For contrast C>P (see Figure, green), a huge cluster extended bilaterally from FG, parahippocampal and lingual gyrus (LG) to cuneus, precuneus and superior parietal lobule, as well as to MTG (BA 37) and middle occipital gyrus, angular gyrus (BA 39), cingulate, caudate, thalamus, cerebellum, and midbrain. Discussion Impact of phonological distractors (P>C) was an increase of activation in areas associated with acoustic representations and word form retrieval (STG, insula), phonological store (SMG/inferior parietal lobule), auditory-motor interface (left parietal operculum), and word form encoding (IFG). Activation of an acoustic area suggests that phonological facilitation already occurs at the auditory input stage. Activation of postcentral gyrus may be attributed to feed-forward facilitation of articulatory processes. Categorical distractors (C>P) revealed areas related to visual recognition and mental imagery (middle occipital, LG, FG), episodic memory retrieval and associations (cuneus, precuneus, post. cingulate), conceptual-semantic processing (angular, FG), sound-meaning interface (MTG), and distractor/response inhibition (ant. cingulate, right IFG). Activation of areas related to articulation (e.g., cerebellum) may again reflect feed-forward priming. Thus, we were able to segregate (lexical)-semantic and phonological processing stages in this paradigm. References Abel, S., Dressel, K., Bitzer, R., Kümmerer, D., Mader, I., Weiller, C., & Huber, W. (2009). The separation of processing stages in a lexical interference fMRI-paradigm. *NeuroImage*, 44, 1113-1124. Alario, F. X., Segui, J., & Ferrand, L. (2000). Semantic and associative priming in picture naming. *The Quarterly Journal of Experimental Psychology*, 53A, 741-764. De Zubicaray, G. I., Wilson, S. J., McMahon, K. L., & Muthiah, S. (2001). The semantic interference effect in the picture-word paradigm: An event-related fMRI study employing overt responses. *Human Brain Mapping*, 14, 218-227. De Zubicaray, G. I., McMahon, K. L., Eastburn, M. M., & Wilson, S. J. (2002). Orthographic/phonological facilitation of overt responses in the picture-word task: An event-related fMRI study using overt vocal responding. *NeuroImage*, 16, 1084-1093. Hickok, G. & Poeppel, D. (2004). Dorsal and ventral streams: a framework for understanding aspects of the functional anatomy of language. *Cognition*, 92, 67-99. Indefrey, P. & Levelt, W. J. M. (2004). The spatial and temporal signatures of word production components. *Cognition*, 92, 101-144. Mechelli, A., Josephs, O., Lambon Ralph, M. A., McClelland, J. L., & Price, C. J. (2007). Dissociating stimulus-driven semantic and phonological effect during reading and naming. *Human Brain Mapping*, 28, 205-217. Rubia, K., Smith, A. B., Taylor, E., & Brammer, M. (2007). Linear age-correlated functional development of right inferior fronto-striato-cerebellar networks during response inhibition and anterior cingulate during error-related processes. *Human Brain Mapping*, 28, 1163-1177. Vigneau, M., Beaucousin, V., Hervé, P. Y., Duffau, H., Crivello, F., Houdé, O., Mazoyer, B., & Tzourio-Mazoyer, N. (2006). Meta-analyzing left hemisphere language areas: Phonology, semantics, and sentence processing. *NeuroImage*, 30, 1414-1432.

32. Brain activity during speech production: searching for markers of stuttering persistency. A. Choo (1), S. Kraft (1), N.G. Ambrose (1), H. Sharma (1) and T. Loucks (1). (1) *University of Illinois at Urbana-Champaign, Urbana, US.* Identifying the cause of developmental stuttering is hindered by the lack of a biomarker to predict if an at-risk child will develop this disorder or if it will become chronic. Biomarkers may involve behavioral measures, genetic markers, or neurological differences. Functional brain imaging has consistently indicated differences between adults who stutter (AWS) and fluent speakers, which are potential markers of stuttering. It remains unknown if these differences reflect the underlying cause or plastic changes from coping with a disorder. Studies in children are needed to resolve this question. In this study, we use fMRI to identify potential markers of stuttering in a cross-sectional design involving adults and children. Data from 11 AWS and 10 adult controls are reported here (20-35 years, right-handed, monolingual English speakers). Testing of children is in progress. In

separate conditions, participants either named pictures using overt speech or engaged in covert phoneme monitoring while listening to words in a 10 second ON/OFF block design. Thirty blocks of pictures and auditory stimuli were presented. Robust BOLD activity was found in both groups for each task in speech and language brain areas and visual cortex. Overt speech elicited BOLD activity in bilateral primary oral sensorimotor regions, auditory regions, supplementary motor area (SMA), inferior frontal gyrus (IFG), thalamus and cerebellum. Activity during phonological processing was similar with the main exception of oral motor cortex. Within group contrasts indicated activity during picture naming was more intense in frontal regions and SMA while phoneme monitoring showed higher auditory activity. The group contrast of picture naming indicated AWS had more intense activity in the left motor cortex and the right IFG, right superior temporal sulcus (STS) and right middle temporal gyrus (MTG). Group differences were not detected for phoneme monitoring. Overall, AWS and fluent controls showed similar activity with differences only apparent during speech. The increased activity in left hemisphere sensorimotor cortex and right frontal areas in AWS is consistent with previous studies. The increased right STS/MTG activity in AWS is of interest because its left hemisphere homologue is associated with semantic access and retrieval. It appears that AWS showed a right lateralized emphasis or 'bias' in regions associated with speech and language processing and 'over-activity' in left motor regions. Activity associated with a biomarker for this disorder is difficult to parse from potential coping effects in adults, but provides baseline data for comparison with children who are being tested.

33. Neural Correlates of Verb Inflection Production: fMRI Study of Tense and Agreement Morphology. A. Kiehl (1,2), S.C. Fox (1,2), B. Bonakdarpour (1,2), T.B. Parrish (4), and C.K. Thompson (1,2,3) (1)Aphasia and Neurolinguistics Research Laboratory, Northwestern University, US (2)Department of Communication Sciences and Disorders, Northwestern University, US (3)Department of Neurology, Northwestern University, US (4)Department of Radiology, Northwestern University, US.

Introduction: Most neuroimaging studies examining verb morphology have focused on verb tense morphology, with agreement processing largely ignored. In addition, results of these studies vary considerably due to differences in task demands and other methodological details. For example, some studies have used overt production tasks, whereas others have used covert tasks (Beretta et al., 2002; Jaeger et al., 1996). In the present study we undertook a direct comparison of brain activation associated with tense, and agreement morphology under overt and covert production conditions. Models of language representation and processing differ in where tense and agreement inflections are instantiated in the phrase structure and what functions are served by the two forms (Bobaljik & Thrainsson, 1998; Friedmann & Grodzinsky, 1997; Pollock, 1989). Further, tense and agreement can be selectively impaired in patients with agrammatic aphasia (Friedmann & Grodzinsky, 1997; Lee et al., 2008), suggesting that the neural signatures for the two forms may vary somewhat. We, therefore, undertook the present study to examine the neural mechanisms of the two forms in both overt and covert fMRI tasks. Methods: An event-related fMRI design was used to examine verb inflection production in 14 healthy adults. Production of verbs inflected for tense (V + -ed) and agreement (V + -ed) was elicited using temporal adverbs (i.e. Yesterday, Nowadays), and the cue word "Say" was used to elicit production of verb stems. For example, the cue word 'yesterday' and the verb 'paint' were visually presented and the participants were expected to respond "painted". Results: When activation of tense and agreement was contrasted with that of the stem condition normal participants recruited a widely distributed neural network involving the frontal (BA 44/47), temporal (BA 22), and parietal brain areas (BA 7 & 37). The exact pattern of activation varied with the demands of the production task. Although several regions in the anterior and posterior cortex were activated in both conditions, activation in the overt task extended more posteriorly into the right fusiform gyrus (BA 37), and bilaterally into the inferior and middle occipital regions (BAs 17, 18). Additionally, tense activated a greater number of brain areas than agreement, including inferior frontal (BA 47), cingulate (BA 24) and supra-marginal gyri (BA 40). Conclusions: The results of this study indicate that in healthy adults inflecting verbs for grammatical morphology involves a distributed neural network bilaterally. Our findings identify the neural correlates of verb inflection production in healthy participants and may provide an insight into dysfunction of grammatical morphology associated with aphasia and treatment of language disorders.

34. In-vivo animation of event-related gamma-oscillations to understand human language. E. Asano (1). Children's Hospital of Michigan, Wayne State University, Detroit, US.

Objective: To evaluate the utility of a new neuroimaging method which we refer to as 'in-vivo animation of event-related gamma-oscillations'. Methods: The dynamic changes of gamma-oscillations elicited by language tasks were animated on a three-dimensional MR image in epileptic children who underwent chronic electrocorticography in our institute between 2006 and 2009. The sites showing augmentation of gamma-oscillations were correlated with the results of electrical neurostimulation. Results: Experiment 1 (overt repetition task): Overt repetition of an auditorily-presented syllable elicited gamma-augmentation sequentially involving the superior temporal gyrus, the inferior Rolandic area and the superior temporal gyrus in the recorded hemisphere. Subsets of the inferior Rolandic sites, more frequently on the left side, showed differential gamma-augmentation elicited by articulation of phoneme [f] more than [h] or phoneme [i:] more than [a:]. Experiment 2 (overt semantic naming task): Overt naming following an auditorily-presented verbal question elicited gamma-augmentation sequentially involving the superior temporal gyrus, the middle-inferior temporal gyri, the inferior frontal gyrus, the inferior Rolandic area and the superior temporal gyrus on the left hemisphere. Experiment 3 (overt word reading and color naming tasks): Overt reading of congruently and incongruently colored words commonly elicited gamma-augmentation involving the left inferior occipital-temporal area immediately following presentation of stimuli and the left inferior Rolandic area during

naming responses. On the other hand, overt color-naming of incongruently colored words (also known as Stroop color-naming task) elicited gamma-augmentation in the left premotor region prior to naming responses, in addition to the above-mentioned areas. Statistical analyses suggested that electrical neurostimulation of sites showing event-related gamma-augmentation, in general, elicited congruent clinical symptoms more frequently than that of the remaining sites did. For example, sensorimotor symptoms involving the mouth were frequently elicited by neurostimulation of the left Rolandic sites showing phoneme-specific gamma-augmentation; expressive aphasia was elicited by neurostimulation of the left premotor sites showing gamma-augmentation specifically associated with the Stroop color-naming task. Conclusion: This novel method can delineate not only 'what' but also 'how' cortices are activated during various language tasks. The results of neurostimulation have provided internal validation to this method. The benefits of event-related gamma-oscillations on electrocorticography include (i) minimal artifacts derived from cranial muscles or head movement during overt vocalization, (ii) a temporal resolution of 10 milliseconds, and (iii) a better signal-to-noise ratio compared to scalp electroencephalography and magnetoencephalography, which record cortical signals from outside of the scalp. The drawbacks include: (i) electrocorticography is inevitably associated with spatial sampling limitations, (ii) measurement is not tenable in healthy humans and (iii) the effects of antiepileptic drugs may alter the findings.

35. Phonological access aphasia: behavioral and lesion characteristics. S. Berentsen (1,2), J.R. Binder (1), J. Morton (1), and M. Seidenberg (2). (1) Medical College of Wisconsin, Milwaukee, US. (2) Rosalind Franklin University, North Chicago, US.

Cognitive models of language identify distinct phonological (sound-based), semantic (meaning-based), and syntactic (generative rule-based) processing systems. These constructs, which refer to distinct classes of information representation and access, could provide a more theoretically coherent classification system for aphasic impairments than traditional syndrome-based schemes. Phonological access -- retrieval of a mental representation of a word's sound -- is a core process in all speech production tasks, including repetition, reading aloud, naming, and discourse. It is distinct from motor sequencing and articulation, and can be assessed without overt speech production. We define Phonological Access Aphasia (PAA) as a relatively isolated impairment in the ability to access word sound information, without accompanying semantic access impairment. Phonological access was measured using a visual rhyme matching task that does not require overt speech. 24 unselected left middle cerebral artery stroke patients (9 men, 15 women, mean age = 59, mean time from stroke onset = 1025 days) were tested on 2 silent reading tasks: Rhyme Matching (match SOUTH to YOUTH or MOUTH based on rhyme) and Semantic Matching (match HORSE to BEAR or COW based on similarity of meaning). Z-scores for these tests were based on the performance of 22 age and sex matched controls. 8 patients (33%) had PAA, defined as a Rhyme Matching Z-score below -5, a Semantic Matching Z-score above -5, and a difference of at least 5 SD between phonological and semantic scores. 6 patients had no phonological impairment, and 10 had both phonological and semantic impairments. Lesioned areas were identified using structural MRI. Lesions from patients with normal phonological access were subtracted from the lesion area identified in patients with PAA. Maximal overlap for patients with PAA occurred in the left supramarginal gyrus and posterior superior temporal gyrus. Although phonological abilities are typically tested with overt speech production tasks (e.g., repetition, reading aloud, naming) the rhyme judgment task used demonstrates that PA impairment is independent from overt speech articulation. PA impairment is a component of both classical Conduction and Wernicke's aphasia syndromes and underlies the phonemic paraphasia and anomia that occur in these syndromes. We suggest that "phonological access aphasia" is preferable to these syndrome-based terms in that it specifies the actual processing impairment that occurs in these patients.

36. Characterization of electroencephalographic (EEG) components elicited by overt speech production in the picture naming task. F.-X. Alario (1), S. Riès (1), N. Janssen (1,2), S. Dufau (1), and B. Burle (1). (1) Aix Marseille Université & CNRS, Marseille, France (2) Universidad de La Laguna, Tenerife, Spain.

We characterized a sequence of electroencephalographic (EEG) components elicited by the picture naming task. EEG has scarcely been used to investigate the neural processes of speech production, presumably because of feared contamination of the EEG signal by the artefacts generated by articulation. We addressed this challenge using a blind source separation algorithm based on the canonical correlation analysis. Clean EEG data was successfully obtained. Furthermore a surface Laplacian transformation of the signal was computed. Following these temporal and spatial data pre-processing, a clear succession of activities became apparent. Between 95 and 160 ms post-stimulus, a sequence of visual evoked potentials were observed. These were followed by the emergence of more sustained fronto-central activities, best seen time-locked to the response. Peaking 250 ms before vocal onset, we observed an activity over the supplementary motor area which resembles activities previously associated with decision-making processes. Shortly after vocal onset, there was a clear negativity (peak 45 ms) similar to the one reported previously with segmental responses, and that likely reflect performance monitoring. This negativity was followed by activity over the left temporal cortex (peak 178 ms). Post-hoc analysis revealed that these activities were differentially affected by visual complexity, picture name lexical frequency and length. A tentative interpretation of these observations provides a window on the temporal sequence of mental operations underlying picture naming.

37. Separable effects of language practice and task familiarity after lexical training in normal subjects: an fMRI study. G. Miceli (1), G. Basso (1), R. Capasso (1)(2), S. Magon (1), G. Monittola (1), F. Reggiani (1), F. J.

Yang (1). (1) CIMeC (Centro Interdipartimentale Mente/Cervello), Università di Trento, Rovereto, Italy (2) Fondazione Santa Lucia IRCCS, Rome, Italy

GOAL: Anomia is the most frequent sign of aphasic speech. Its treatment relies on the repeated production of target words. Behavioral studies show that anomia can improve after speech therapy; however, the neural substrate underlying recovery is unclear. To begin understanding neuroplasticity phenomena correlated with recovery of speech, we trained healthy subjects on low-frequency words, by the same technique used in anomia treatment, and analyzed fMRI activations before and after training. **METHODS:** Ten right-handed (3 men, mean age: 32.7), healthy Italian speakers overtly named black-and-white drawings (naming task) or pronounced a pre-learned pseudoword when seeing a squiggle (control task), during an event-related fMRI experiment. To-be-named stimuli consisted of two subsets of 20 low-frequency items (target LF set: average frequency = 3.0 ± 2.15 ; non-target LF set: average frequency = 3.4 ± 2.13) and of 20 high-frequency items (HF: average frequency = 57.7 ± 49.31). Sixty pictures and 20 squiggles were presented, one every 11.5 sec. Each stimulus lasted 2 s. Each participant completed training (repeated oral naming) on the target LF set during 10 consecutive days. fMRI sessions took place before and after training (mean interval: 13.2 days). BOLD fMRI was performed with an echo-planar gradient-echo sequence running on a 4T scanner. Analyses were performed with Brainvoyager QX 1.9. Functional volumes were realigned, spatially normalized to Talairach space and smoothed. Task, training and session factors were modeled using a random effect ANOVA group analysis. **RESULTS:** Contrasts between second and first fMRI demonstrated decreased activation in the posterior portion of the left middle temporal and right superior temporal gyri (BA 22), in the lowermost portion of pre- and post-central gyri extending to premotor areas bilaterally (BA 43/6), and in the left middle occipital gyrus (BA 18/19). The only common area of increased activation was in the right cerebellar hemisphere. HF words yielded increased activation in the posterior cingulate gyrus above the callosal splenium (BA 23/31). Target LF words activated the same region, as well as a medial area across the parieto-occipital sulcus, between precuneus and cuneus (BA 7/18/19/31). Directly contrasting target and non-target LF words in the second fMRI confirmed increased bilateral activation for target LF words at the border of precuneus and cuneus across the parieto-occipital sulcus (BA 7/18/31), and in the posterior cingulate gyrus above the callosal splenium (BA 23/30/31). Crucially, this differential activation was not found when LF target and non-target words were directly contrasted in the first fMRI. **DISCUSSION AND CONCLUSIONS:** Decreased activation in left BA 22 and bilateral BA 43/6 for all stimulus sets during the second fMRI, might be the neural counterpart of task adaptation. Activation of the posterior portion of the precuneus has been observed in studies involving learning, even in the absence of explicit recall, and has been associated with successful retrieval attempts. Cingulate activation has been linked to recognition of previously presented items. In our study, training-specific activation of the precuneus and posterior cingulate cortex during presentation of trained LF words might reflect increased ease of retrieval when naming a trained item.

38. Seeing it, understanding it, and finding its name within 200 milliseconds? An MEG study of picture naming using multiple linear regression. M. Miozzo (1, 2), O. Hauk (3), and F. Pulvermüller (3). (1) University of Cambridge, Cambridge, UK (2) Johns Hopkins University, Baltimore, US (3) MRC Cognition and Brain Sciences Unit, Cambridge, UK

In order to produce a word successfully, speakers need to retrieve different kinds of information about the target word including its meaning, syntactic features, and sound. Various lines of evidence obtained from brain-damaged patients with acquired language deficits and neuroimaging studies have revealed that partially distinct neural networks are implicated in the retrieval of the semantic, syntactic, and phonological features of words. A critical question for understanding word production concerns when these different neural networks become active and the different word features are processed. We addressed this question in an MEG experiment of spoken picture naming using linear regression. Based on a number of measures of the pictures and their names, we identified four predictor variables, each associated with the retrieval of a different type of information critical for word production in picture naming: visual features, semantic features, information related to object use, and phonological features. Regression coefficients were obtained for individual predictor variables at each latency and sensor. Data for individual participants were interpolated to standard sensor geometry, and source estimates were computed in a standardized boundary element model. Statistical analyses were performed in sensor space using the SPM5 approach based on random field theory. We controlled for activation induced by preparation for articulation. The earliest effect appeared with visual features, starting around 90 ms after picture presentation and involving occipital areas bilaterally. An effect of semantic features was detected soon after, starting at about 140 ms and extending within the perisylvian areas bilaterally. An effect of phonological features arose at a similar time (about 140 ms) within left pre-central areas. Activation associated with action-related information started to appear slightly later (about 270 ms) around left postero-inferior areas. The effect of these variables lasted up to about 300 ms, with the exception of visual features, whose effect ceased earlier. Our results suggest that semantic and phonological features of words start to be processed fairly early and simultaneously. These results are consistent with accounts of word production that propose extremely rapid cascading of activation from visual recognition processes to semantic and phonological processes. The finding that areas associated with action were activated even in a task that did not require action responses other than speaking confirms that action-related features are part of the semantic information that is automatically retrieved in object identification and word naming. The finding of a relatively late effect of action-related features may reflect additional processing that is required to identify the visual components of objects that are specifically associated with actions.

39. Relationships between Cortical Stimulation Error Type and Cytoarchitectonics. B.C. Loudermilk(1,2), L. Detwiler (3), G. Ojemann (4), J.F. Brinkley (3), and D.P. Corina (1,2). (1) Department of Linguistics, University of California, Davis, California (2) Center for Mind and Brain, University of California, Davis, California (3) Departments of Biological Structure and Medical Education and Biomedical Informatics, University of Washington, Seattle, Washington (4) Department of Neurosurgery, University of Washington, Seattle, Washington

Cortical stimulation mapping (CSM) is a widely-used technique for identifying functionally essential cortex in patients undergoing cortical resection. Considered to be a gold standard among alternatives, CSM guides clinical decisions by identifying important cortical regions such as the motor, sensory, and language cortices (Lesser R et al., 2008). Neuronal depolarization through cortical stimulation can result in a temporary functional lesion that interferes with the task demands, such as confrontation naming (Gordon B et al., 2001). However, during CSM, it is not uncommon to observe naming errors following a previously stimulated trial. That is, the occurrence of a naming deficit despite the fact that the stimulator was not contact with the cortex at the time of the error (i.e. no stimulation was delivered). Moreover, these errors occur in the absence of after-discharge activity. We refer to these errors as “following stimulation errors” or FSEs (Corina DP et al., 2005). The properties and characteristics of FSEs are poorly understood and to our knowledge, these errors have not been treated in the literature. In this poster, we attempt to characterize FSEs in terms of their neuroanatomical distribution as well as the error types they engender. We identified 40 patients (370 error trials) from a repository of human brain mapping data by querying the database on 4 error types: semantic paraphasias, phonological paraphasias, performance errors, and off-target errors. We observed differential patterns of stimulated errors and FSEs in both error type and location. FSEs were primarily associated with semantic paraphasias; in contrast, relatively few FSEs were performance errors ($\chi^2 = 21.955$, d.f. = 3, $p < 0.0001$). The distribution of stimulated errors and FSEs across error-prone regions was also significant ($\chi^2 = 27.58$, d.f. = 9, $p = 0.001$). In particular while temporal sites and regions bordering the central sulcus show evidence for post-stimulation effects, the supramarginal gyrus does not. This region, which consists of homotypical type 3 cortex characterized by prominent granular cells, appears relatively immune to post-stimulation effects. In contrast, in much of the temporal lobes, but also the postcentral gyrus, which consist of type 2 homotypical cortex, significantly greater numbers of FSEs were observed. The anatomical distribution of FSEs suggests that cortical regions are not equipotent to post-stimulation effects. Subtle conductivity differences in cytoarchitecture may possibly play a role in these effects. From a clinical perspective, these findings support disregarding FSEs for purposes of guiding surgical decisions. In striving to understand the neurobiology of language our findings may indicate linkages between cortical cytoarchitectonic properties and differential components of the language system, specifically those that support lexical-semantic language properties versus articulatory performance.

40. Ventral and dorsal white matter pathways for phonological transformation processes. P. Kellmeyer (1,2), Saur, D. (1,2) C. Peschke (3), J. Kappes (4), W. Ziegler (4), C. Weiller (1,2), A. Baumgärtner (5). (1) Department of Neurology, University Clinic Freiburg, Germany (2) Freiburg Brain Imaging (3) Department of Systems Neuroscience, University Medical Center Hamburg-Eppendorf, Germany (4) Clinical Neurophysiology Group, Hospital Munich-Bogenhausen, Germany (5) Department of Health Sciences, University of Applied Sciences Fresenius, Hamburg, Germany

Objectives: This study investigates white matter fiber pathways for phonological transformation processes which were tracked by diffusion tensor imaging (DTI) in a large-scale language network which was functionally defined by a functional magnetic resonance imaging (fMRI) experiment investigating different phonological transformation processes in German. In the fMRI study two types of phonological transformation were performed by subjects in the scanner, a suprasegmental transformation task in which a pseudo-country had to be transformed into a pseudo-language which required a shift of stress placement. In a segmental transformation task, in turn, a vowel segment change was elicited by having subjects transform a pseudo-noun into a pseudo-diminutive, or vice-versa. Methods: DTI images were acquired from 20 subjects (mean age=34 y, range=20-69 y, 8 females). Language areas were defined based on the results from the fMRI experiment contrasting suprasegmental and segmental transformation, respectively, with repetition. Fronto-parietal as well as interhemispheric pathways between these functionally defined core-regions were tracked with a probabilistic diffusion-tensor based imaging method. Results: Connectivity between areas active during suprasegmental transformation, that is left inferior parietal lobule (IPL), intraparietal sulcus (IPS) and left inferior frontal gyrus (IFG), pars opercularis (BA 44) was provided by a dorsal pathway via the arcuate fascicle (AF) and superior longitudinal fascicle (SLF) fiber system. Areas active during segmental transformation, namely IPL, IPS and IFG, pars triangularis (BA 45) are connected in both hemispheres by a ventral pathway via the extreme capsule (EmC), while IPL and IFG (BA 44) are connected by a dorsal pathway via the AF/SLF fiber system. Conclusions: The segregation of language related white-matter pathways into dorsal and ventral pathways (Saur et al., 2008) suggests a functional-anatomical dissociation for different processing routines. For phonological processing, the dorsal pathway seems to act as a fast, bottom-up route for mapping suprasegmental and segmental phonemic information from phonological short-term store in IPL to the inferior-frontal articulatory network, whereas the ventral pathway could be important for top-down modulation based on lexical-semantic information. It will be interesting to further investigate, how disruptions of particular subcomponents of this parieto-frontal network and the connecting dorsal and ventral pathways affects specific processing routines, like phonological transformation processes.

41. Inter- and Intra-hemispheric functional connectivity differs during speech and non-speech production in stuttering speakers. S. Chang (1), B. Horwitz (2), and C.L. Ludlow (1). (1) Laryngeal and Speech Section,

NINDS/NIH, Bethesda, MD (2) Brain imaging and Modeling Section, NIDCD/NIH, Bethesda, MD.

Functional neuroimaging studies in developmental stuttering have shown discrepant activity patterns in stuttering adults in the inferior frontal gyrus (IFG; BA44) and posterior superior temporal gyrus (pSTG) in the left hemisphere and heightened activity in the right hemisphere homologues during speech production. Diffusion tensor imaging has revealed white matter differences in left frontal-temporal pathways in chronically affected adults and children. To examine functional connectivity in stuttering, we used previously published fMRI data (Chang et al., 2009) from right-handed 21 SS and 21 controls to conduct Psychophysiological interaction (PPI) analysis, a measure of functional connectivity (FC). Our hypothesis was that stuttering speakers, relative to controls, would have decreased FC between the left auditory and motor regions and heightened FC between the left and right homologues during oral motor production tasks. In each trial, two nonsense syllables or two non-speech oral sounds were presented auditorily one at a time, which the subject later produced on cue. For PPI analysis, seed coordinates for the bilateral IFG (BA44) were identified from each subject's task-specific functional data and multiplied by anatomically defined probability maps for BA44. Time courses of the seed regions were extracted using an 8 mm sphere centered on the seed coordinate for each condition. The general linear model examined the predictor variables task, activity in the bilateral IFG and interaction between these variables. All PPI maps were thresholded at $Z=2.69$ ($p<0.025$, corrected). When the seed was placed in the LIFG, there was significantly increased FC relative to rest with the left motor precentral gyrus (LPrCGy) and LpSTG during both speech and non-speech production in controls. In SS, no significant increases in FC were found with LIFG in either the LpSTG or LPrCGy for either task. When seed was placed in the RIFG, controls did not show any regions with significant FC increases. In SS, significant increases in FC were found with RIFG in bilateral motor and auditory regions including the LPrCGy, LpSTG, LSMG, RpSTG, and RSMG. In conclusion, SS lacked strong FC between the LIFG and LpSTG for production but extensive FC with RIFG in both hemispheres. The aberrant FC observed in stuttering subjects likely demonstrates a lack of left hemisphere specialization for efficient oral-motor sound production during both fluent speech and non-speech production.

42. ERP correlates of word production before and after stroke in an aphasic patient. M. Laganaro (1), S. Morand (2), C.M. Michel (3), L. Spinelli (3), A. Schnider (3). 1. University of Neuchâtel, Neuchâtel, Switzerland 2. University of Glasgow, Glasgow, UK 3. University Hospital and University of Geneva, Geneva, Switzerland.

Event-related electrophysiological (ERP) investigation on changes during language processing after stroke usually compared aphasic patients to healthy controls (Friederici et al., 1999; Dobel et al., 2001; Angrilli et al., 2003; Pulvermüller et al., 2004; Breier et al., 2004; Laganaro et al., 2009; Cornelissen et al., 2003), since pre-stroke data is normally not available. A major problem for the interpretation of these results concerns the between-subject variability, which might prevent from teasing out differences due to the pathological conditions and those due to variability. Here we present the study of an aphasic patient with severe anomia who had incidentally performed a picture naming task in an ERP study as a control subject one year before suffering a stroke. This unlikely situation allowed to carry out comparisons before and after stroke in the same subject. **Method** The patient is a 68 year-old man who suffered a left fronto-temporal parietal hemorrhagic stroke with initial Wernicke aphasia. Four months post-stroke he presented with severe anomia characterized by many phonological paraphasias, relatively spared auditory and written comprehension and severe agraphia. High-resolution EEG was recorded at 3, 4 and 5 months post-stroke during the same delayed picture naming task that he had already performed as a control subject one year earlier. Differences between pre- and post-stroke recordings and between the patient and a control group were tracked on amplitudes and on the sequence of stable topographic maps (reflecting the sequence of functional microstates, (Lehmann & Skrandies, 1984; Murray et al., 2008)). **Results** The subject did not differ from other healthy subjects before his stroke, but presented major electrophysiological differences after stroke both in comparison to himself before stroke and to the control group. Different amplitudes and topographic maps after stroke consistently appeared from about 250 ms after picture presentation and remained very stable at 3, 4 and 5 months post-stroke. A single divergent but stable topographic configuration of the scalp electric field characterised the divergent pattern. The cortical generator of this stable divergent micro-state, localized with the patient's own post-stroke head model, remained limited to the posterior part of the middle and inferior left temporal lobe. **Conclusion** The accidental recording of this patient's brain activity before his stroke confirms that differences observed when comparing the electrophysiological data of stroke patients to a control group are not due to inter-individual variability and can reliably be interpreted as the consequence of the brain lesion. The unchanged ERP correlates from 0 to about 250 ms after picture onset and the time-window of electrophysiological changes observed in this patient after stroke confirm that divergent ERP patterns observed during a language production task after stroke appear in specific time-windows, which can be related to impairment in specific cognitive processes (Laganaro et al. 2009). **References** Angrilli, A., Elbet, T., Cusumano, S., Stegagno, L. & Rockstroh, B. (2003). Temporal dynamics of linguistic processes are reorganized in aphasics' cortex: an EEG mapping study. *NeuroImage*, 20, 657-666. Breier, J.I., Castillo, E.M., Boake, C., Billingsley, R., Maher, L., Francisco, G., & Papanicolaou, A.C. (2004). Spatiotemporal patterns of language-specific brain activity in patients with chronic aphasia after stroke using magnetoencephalography. *Neuroimage*, 23, 1308-1316. Cornelissen, K., Laine, M., Tarkiainen, A., Jarvensivu, T., Martin, N. & Salmelin, R. (2003). Adult Brain Plasticity Elicited by Anomia Treatment. *Journal of Cognitive Neuroscience*, 15, 444-461. Dobel, C., Pulvermüller, F., Härle, M., Cohen, R., Köbbel, P., Schönle, P.W., Rockstroh, B. (2001). Syntactic and semantic processing in the healthy and aphasic human brain. *Experimental Brain Research*, 140, 77-85. Friederici, A.D., von Cramon, Y. & Kotz, S.A. (1999). Language related brain potentials in patients with cortical and subcortical left hemisphere lesions. *Brain*, 122, 1033-1047. Laganaro, M., Morand, S. & Schnider, A. (2009). Time course of evoked-potential

changes in different forms of anomia in aphasia. *Journal of Cognitive Neuroscience*. In press. Lehmann, D., & Skrandies, W. (1984). Spatial analysis of evoked potentials in man—a review. *Prog Neurobiol*, 23,227--250. Murray, M.M., Brunet, D., & Michel, C. (2008). Topographic ERP analyses, a step-by-step tutorial review. *Brain Topography*, 20, 249-269. Pulvermüller, F., Mohr, B., & Lutzenberger, W. (2004). Neurophysiological correlates of word and pseudo-word processing in well-recovered aphasics and patients with right-hemispheric stroke. *Psychophysiology*, 41,584-91

43. Impact of aphasia on fluency in natural language. K.Hird (1), K. Kirsner (2). (1) *University of Notre Dame Australia (Fremantle); University of Western Australia.* (2) *University of Western Australia*

One of the most significant challenges facing the Neurobiology of Language involves the relationships between different levels of description. Three obvious levels of description involve language sampling methods, models of language production, and the tracking of metabolic and hemodynamic changes in the brain. However, as developments in each of these levels are in a constant state of flux, re-adjustment is a constant issue. One such issue concerns granularity. Whereas recent work in neuroscience is concerned with functional interaction involving large-scale brain networks (Perlberg and Marralec, 2008), language research tends to focus on de-contextualized tasks, the performance of particular word types, and theoretical models that rely on modularity. The objective of this paper is to describe a language paradigm that might provide a better fit between the methods and models of language production research on the one hand, and the complex systems assumed by fMRI research on the other. We will use results from a clinical trial involving a small sample of aphasics to assess the viability of the new paradigm. De-contextualized tasks dominate language sampling procedures for aphasia and other communication disorders, and the parameters and models associated with these tasks reflect the same general paradigm (Wilke, Lidzba & Krageloh- Mann, 2008). It is our contention that the new neuro-imaging procedures demand an equivalent refinement in the sampling domain, and that the collection and analysis of natural language samples is essential. This paper describes a measurement system designed to quantify fluency in natural language. The system classifies environmental and breathing noise, and estimates means and standard deviations for the three lognormal distributions associated with spontaneous speaking: short pauses, long pauses and speech segment duration (Kirsner, Dunn, Little & Hird, in preparation). We describe three cases with different patterns of deformation; Case A, with a significant increase in the duration of the mean for the long pause distribution coupled with a significant reduction in the rate of correct information units per second; Case B, with a significant reduction in the means of the short and long pause distributions, and Case C, with a significant increase in the short pause or 'articulatory' distribution. The aphasic cases were compared with a control group of 13 participants without communication disorders. The results highlight the sensitivity of the fluency measure revealed by brain damage. Brain damage can give rise to independent or correlated changes across the parameters, depending on the type and extent of damage. The system yields objective and sensitive measures of communicative efficiency for individuals and across a variety of speaking contexts.

44. Language Profile of Parkinson's Disease: Before and After Pallidotomy Surgery. A. Hancock (1), G. Schulz (1). (1) *The George Washington University, Washington, D.C., US*

Background Generally, patients with PD demonstrate a language profile similar to other patients with dorsolateral prefrontal lesions: limited comprehension and production of complex syntax and reduced informativeness (Hancock, et al., 2005, Illes, Metter, Hanson, Iritani, 1988). Pallidotomy often alleviates motoric impairments in PD; however, little is known about the effect on language. Indications are that speech, language, and cognition are minimally affected by neurosurgery performed to alleviate symptoms of PD (Farrell, et al., 2005; Gironell, et al., 2003; Schulz, Greer, & Friedman, 2000 & 2004). This study aims to: 1) Report language performance in PD for picture description, narrative, and conversational tasks. 2) Compare language samples of these tasks performed before and after unilateral posteroventral pallidotomy (PVP) surgery for PD. **Method** Twenty-five patients with Parkinson's disease performed a language battery before and 3-6 months after PVP surgery (13 left, 12 right PVP). Ten healthy people comprised the comparison group. Participants described the "Cookie Theft" picture, narrated a story for "The Cat Story", and engaged in a brief conversation. At the time of submission, six PD patients (three with mild speech impairments, three with moderate) pre and post PVP and five healthy participants have been transcribed, coded, and analyzed with the exception of the conversational condition. The remaining samples have already been collected and will be completely analyzed and incorporated soon. **Language tasks** were coded for Correct Information Units (CIUs), cohesion, and total number of words. In addition, the "Cookie Theft" picture description was coded for Content Units (CU) and Interpretive Content Units (CUi) and the "Cat Story" narrative was analyzed for type of structure and total number of complete and incomplete episodes. **Results** No significant differences were found between healthy adults and Pre PVP patients for total words, rate, CIUs, CUs per minute, or Ratio of Interpretive CUs to total CUs. Percentage of words that were CIUs was different between groups for the Cat Story, but not the Cookie Theft description. Total number of CUs was significantly different between groups. Within the PD group, no statistically significant differences were found between pre and post PVP results across tasks for total words, rate, CIUs, and percentage of words that were CIUs. No significant differences between pre and post PVP were found when analyzing the Cookie Theft picture description for total number of CUs, CUs per minute, and Ratio of Interpretive CUs to total CUs. **Conclusion** In summary, very few language deficits were found and no significant change in language was evident after PVP in the 6 patients analyzed thus far. Because current literature suggests deficits only in complex tasks, it is possible that deficits may be revealed when we analyze the conversation samples. The non-significant differences between pre and post PVP may change after analyzing a larger sample and considering severity and/or side of surgery. **Significance** There is insufficient evidence to expect a change (better or worse) in language production after

the PVP surgery. Implications that basal ganglia has limited, if any, involvement in language should be investigated.

45. Language disorders in a Spanish speaker with a rare genetic cause. P. García-Bellido (1) A. Benítez Burraco, and Carmen Orellana (3). (1) University of Oxford, Oxford, UK (2) University of Oviedo, Oviedo, Spain, (3) Hospital La fe, Valencia, Spain.

One of the main objectives in current research is to establish sound correlations between the genetic cause of a language disorder and the structural anomalies in the brain. A rare genetic anomaly which impairs language production (in different degrees) has been reported to one of the authors. This is a case of a girl (A) who has a translocation between chromosomes 7 and 11. Remarkably, the affected chromosome 7 also exhibits a pericentromeric inversion with a rupture in 7p13 and 7q31. We will briefly discuss the significance of this genetic case in view of what is known so far on 7q31, a chromosomal region which encompasses some relevant loci for specific language impairment (SLI) (including the locus for FOXP2, a well-characterized "gene for language"). In order to assess the level of speech and language impairment of A, we will present a comparison between A's Castilian speech and that of a girl matched for age for some general and specific tasks. We will also compare their respective structural differences using the information obtained from MRI analysis. This particular case can contribute to the understanding of the relation between genes, their expression in the brain and the linguistic behaviour which emerges from this complex relation.

46. Comparing electrophysiological correlates of word production in immediate and delayed naming through the analysis of age of acquisition effects. M. Laganaro (1) and C. Perret (1). (1) University of Neuchâtel, Neuchâtel, Switzerland

Most EEG studies analysing speech production with event related brain potentials (ERP) have adopted silent monitoring tasks (Van Turenout et al., 1998; Jescheniak et al., 2002) or delayed picture naming (Vihla et al., 2006; Laganaro et al., 2009) in order to avoid possible artefacts during motor preparation. A central issue in the interpretation of these results is whether the processes implied in those tasks are comparable to those implied in overt (immediate) word production. In the present study we analysed the ERP correlates of immediate and delayed picture naming through the analysis of age of acquisition (AoA) effects, which have been reported with high reliability in reaction time studies (Belke et al. 2005; Bonin et al., 2002). The aim of the study was (1) to investigate the time window of AoA effects and (2) to compare ERPs in immediate and delayed production tasks. **Method** A total of 92 words and their corresponding pictures were selected from French databases. Half of the items were early-acquired and the other half late-acquired words, matched on fifteen other lexical and sub-lexical variables. High-density EEG was recorded in 18 subjects during an immediate and a delayed picture naming task in a counterbalanced order. Artefact-free epochs from 0 to 500 ms relative to pictures onset and backward epochs in the immediate task (from 50ms before the RT) were averaged for each subject and condition. The ERPs were submitted to waveform analyses combined with topographic pattern analyses (Lehmann and Skrandies, 1984; Murray et al., 2008). **Results** A significant 28ms effect of AoA was observed in naming latencies in the immediate condition. Different amplitudes across AoA conditions appeared in immediate naming around 200ms and 300ms after picture onset. Results of the TANOVA analysis also revealed differences between early- and late-acquired words at about 300ms after picture onset. The spatiotemporal segmentation indicated the same sequence of topographic maps in the two AoA conditions, but with a topography lasting 25ms longer in the late-acquired condition. No such effects were observed in the delayed production task. In the comparison between immediate and delayed production differences in amplitudes in the TANOVA analysis started around 300 ms after picture onset. The spatio-temporal segmentation analysis revealed the same sequence of topographic maps until about 400ms, but with different durations. **Conclusion** An effect of word age of acquisition appeared in the immediate picture naming in the time window corresponding to a stable topographic map (functional microstate) which originates around 240ms after picture onset and lasts 130 to 150ms. According to the estimation by Indefrey and Levelt (2004) and to previous ERP results on semantic and phonological encoding (Maess et al., 2002; Vilha et al., 2006; Laganaro et al., 2009), this time-window might correspond to lexical-phonological encoding. Crucially for the interpretation of previous studies, the same functional microstates are observed in the immediate and the delayed naming task from 0 to 400ms, indicating that word encoding processes take place in the delayed naming at least until the beginning of phonological encoding. **References** Belke, E., Brysbaert, M., Meyer, A., S., & Ghyselinck, M. (2005). Age of acquisition effects in picture naming: Evidence for a lexical-semantic competition hypothesis. *Cognition*, 96, B45-B54. Bonin, P., Chalard, M., Méot, A. & Fayol, M. (2002). The determinants of spoken and written picture naming latencies. *British Journal of Psychology*, 93, 89-114. Jescheniak, J.D., Hahne, A. & Schriefers H. (2003). Information flow in the mental lexicon during speech planning: evidence from event-related brain potentials. *Cognitive Brain Research*, 15, 261-276 Laganaro, M., Morand, S. & Schnider, A. (2009). Time course of evoked-potential changes in different forms of anomia in aphasia. *Journal of Cognitive Neuroscience*. in press. Lehmann, D. & Skrandies, W. (1984). Spatial analysis of evoked potentials in man—a review. *Prog Neurobiol*, 23,227-250. Maess, B., Friederici, A.D., Damian, M., Meyer, A.S. & Levelt, W.J.M. (2002). Semantic Category Interference in Overt Picture Naming: Sharpening Current Density Localization by PCA. *Journal of Cognitive Neuroscience*, 14, 455-462. Murray, M.M., Brunet, D. & Michel, C. (2008). Topographic ERP analyses, a step-by-step tutorial review. *Brain Topography*, 20, 249-269. Van Turenout, M., Hagoort, P., & Brown, C. M. (1998). Brain activity during speaking: From syntax to phonology in 40 milliseconds. *Science*, 280, 572-754. Vihla, M., Laine, M., Salmelin, R. (2006). Cortical dynamics of visual/semantic vs. Phonological analysis in picture naming. *NeuroImage*, 33, 732-738.

47. Functional differentiation of the insular cortex: Evidence from speech, language and cognitive processing. V. Gracco (1,2,3), P. Tremblay (4), I. Deschamps (1,2), F-X. Brajot (1,2), E. Klepousniotou (5), L. Copeland (1), I. Itzhak (1,2), S. Baum (1,2), B. Pike (1,2). (1) McGill University, Montreal, Canada (2) Centre for Research on Language, Mind & Brain, Montreal, Canada (3) Haskins Laboratories, New Haven, US (4) University of Chicago, Chicago, US (5) University of Leeds, Leeds, GB.

The insular cortex is located within the lateral sulcus of the brain, completely covered by the frontal, temporal and parietal opercula. Neuroanatomically, the insula sends and receives projections (generally reciprocally) to and from multiple cortical and subcortical sites along its length. Studies of human and nonhuman primates implicate the insular cortex in a wide range of visceral, autonomic, sensorimotor and cognitive functions. Modern functional neuroimaging studies employing a range of speech and language tasks such as syllable and word repetition, sentence production, propositional and nonpropositional speech, verbal fluency, word stem completion, sentence or word generation and reading aloud often report insular activation. More recently insular function has been associated with mirror neuron system properties for emotional recognition and empathy as well as performing a transformational or coordinating function between language processing and speech motor output. Such diverse functions within and across behavioral domains in a single brain structure suggests that the insular cortex is part of either a single, domain general functional system, a set of domain specific functional systems or a system with distributed functions. In order to evaluate the function or functions of the insula related to speech and language, we examined data obtained from multiple functional neuroimaging studies conducted in our lab, representing a wide range speech, language and cognitive processes. The tasks reflect speech production, speech perception (audio, visual and audiovisual), word reading, picture naming, word generation, and cognitive tasks. Here we focused on whole brain analyses of the location of insular activation with a secondary focus on the manner in which additional brain areas implicated in various aspects of speech and language are co-activated with changes in insular activation. Overall, the location of insular activation varied in a systematic manner with the different speech, language and cognitive tasks. A rostrocaudal gradient of insular activation was observed with more cognitive, integrative processes activating the most anterior portions of the insula and more sensory (auditory) processing in the posterior portion of the insula, in a region contiguous with the dorsomedial portion of the planum temporale. Speech and oral motor production was intermediately localized centered on the central sulcus of the insula. In general, all insular activations were bilateral with different degrees of asymmetry depending on the task. Activation in a number of other cortical and subcortical areas displayed a similar systematic change in location with changes observed in insular activation. For example, most anterior portion of the insula, active for more cognitive-like tasks, was mostly associated with concomitant pre-SMA, Broca's area and caudate activation while activation in the more sensorimotor portion of the insula was co-active with the motor cortex, SMA proper and the putamen, without concomitant activation of Broca's area. The results are consistent with the insula as a multifunctional cortical region engaged in many aspects of speech and language behavior from sensory to cognitive processing. The apparent functional specialization along its length and its differential functional connectivity suggests further that the insula is an integral component in a distributed network engaged in sensorimotor integration for multiple behaviors.

48. On the role of the planum temporale in the production of speech. P. Tremblay (1), I. Deschamps (2), and V.L. Gracco (2,3) (1) The University of Chicago, Chicago, US. (2) McGill University, Montreal, Canada. (3) Haskins Laboratories, New Haven, US.

Recent neuroimaging studies have shown that the planum temporale (PT) is activated during the perception of speech but also during the production of speech (Hickok & Poeppel, 2000; 2003; 2007; Tourville et al., 2008) and during non-speech jaw and tongue movements (Dhanjal et al., 2008). This finding has been interpreted as reflecting a role for this area in the integration of sensorimotor information. The objective of this study was to examine the contribution of PT in the production of speech. To this aim, we designed a study that consisted of four experimental conditions that were presented in pseudo-random blocks. These conditions were 1) to whisper a word (Whisper); 2) to whisper a word in the presence of masking pink noise (Whisper Noise); 3) to silently articulate a word (Mimic); 4) to produce a vertical tongue movement twice (Tongue). We chose to use whispered speech because, unlike voiced speech, the generated auditory feedback can be completely masked with noise. In voiced speech, the auditory feedback cannot be completely masked due to the presence of bone conduction. Hence, the whisper and whisper in noise conditions were associated with identical articulation but differed in terms of the presence of auditory feedback. We reasoned that if PT is involved integrating sensorimotor information it should be activated equally in all tasks as each task involves movements of articulators and the processing of somatosensory feedback. If PT is sensitive to the processing of auditory feedback, instead, it should be modulated by the presence of auditory feedback (Whisper > Whisper Noise). Another possibility is that PT is sensitive to articulatory demands, in which case it should distinguish between the non-speech and the speech tasks. Data were acquired on a 1.5T Siemens Sonata MR scanner. In order to eliminate movement artifacts associated with producing speech in the scanner, a sparse image acquisition technique was used. A silent period (6.2 seconds) was interleaved between each volume acquisition (TE = 50 ms, TR = 9.5s, delay in TR = 6.2sec, whole brain coverage), during which participants were instructed to respond. Analyses included whole-brain GLM analyses, cognitive conjunctions, anatomical ROI analysis as well as functional connectivity. The conjunction of all tasks showed no activation in PT. The ROI analyses suggest that PT is more sensitive to the presence of auditory feedback rather than articulation/oromotor demands. Activation was greater in left PT for the Whisper task when compared to either the Whisper Noise or Mimic

condition. The right PT showed greater activation only when the Whisper condition was contrasted with the Whisper Noise condition. The Tongue condition was associated with significantly lower PT activation than all other conditions, suggesting that the PT is more sensitive to the articulatory compared to oromotor demands. To summarize, the main objective of the present study was to investigate the role of PT during speech production. Our results suggest that the main contribution of PT is in the processing of speech auditory, not somatosensory, feedback.

Motor behavior and language

49. On the role of the motor cortices in action observation and naturalistic language tasks. P. Tremblay (1), S.L. Small (1). (1) *The University of Chicago, Chicago, US.*

Behavioral, imaging, and stimulation results converge to support the notion that motor cortical regions, primarily the ventral premotor area and posterior third of the inferior frontal gyrus, contribute to speech perception and possibly language comprehension. This involvement of motor cortices has been observed mostly in the context of passive audio and audio-visual language tasks, most often consisting of single word presentation, and rarely during more naturalistic situations such as the generation of meaningful language. Although it has been proposed that the contribution of the motor system to language perception and comprehension is essential, there is no strong evidence supporting the notion that motor activity per se is causally related to language comprehension or to language at all. The goal of the present study was twofold: First, we wanted to examine the scope of motor cortical activity in language comprehension using a set of naturalistic language perception and language generation tasks. Second, we wanted to test the hypothesis that brain regions involved in producing and understanding actions are also involved in understanding language. To this aim, we constructed five experimental conditions, including (1) passive viewing of simple line drawings representing objects (which were normed for ease of use and manipulability); (2) passive listening of naturalistic sentences describing object related manual actions or visual features (color, shape, etc.) of the same objects; (3) repetition of a similar set of sentences; (4) generation of sentences describing object related manual actions or visual features of objects; and (5) passive viewing of short movies depicting an actor manipulating familiar objects with one hand. The baseline condition consisted of rest. Each experimental condition was acquired in a separate run within which it was alternated with baseline trials. Functional imaging data were collected at 3 Tesla (32 slices, 3*3*4 mm, TE: 0.015sec; volume acquisition: 1.5 sec; delay in TR: 3.5 sec for the speaking tasks, 0sec for the other tasks). Speaking always occurred while the scanner gradients were switched off. Functional data were analyzed using NeuroLens. The data were first realigned to the third frame of the first functional run, the intensity normalized, and the data low-pass filtered using a 6mm FWHM Gaussian kernel. For each run, a set of regressors including the experimental trials and the six movement parameters was convolved with a hemodynamic response function modeled as a difference of two gamma functions. In addition to the GLM analysis, we further evaluated the logical intersection of activity among the different tasks. Preliminary results on a subset of participants indicate that all the language tasks, regardless of whether or not they described actions, were associated with activation in the precentral region, and that the location of this activation overlapped with activation related to watching object pictures and action movies. However, there was a marked reduction in premotor activity for the generation tasks compared to the passive tasks, demonstrating the necessity to use naturalistic language to draw conclusions about the neurobiology of language. Further analysis will examine the network differences (using functional/effective connectivity) for active and passive language tasks, and action observation.

50. At the interface between action verbs and prehension force. V. Frak (1,2), T. Nazir (3), M. Goyette (2), H. Cohen (4), Y. Paulignan (3) and M. Jeannerod (3). (1) *Département de kinanthropologie. Université du Québec à Montréal. Canada.* (2) *Institut de Réadaptation de Montréal. Université de Montréal. Canada.* (3) *CNRS UMR 5015, Institut des Sciences Cognitives, Bron Cedex, France.* (4) *CNRS UMR 8189, Université Paris Descartes, France.*

Action verbs and motor actions activate similar cortical brain areas (Price et al., 1994; Grafton et al., 1998). An increasing number of studies reveal that the sensorimotor components of word meaning activate cortical regions overlapping with the neural systems involved in the perception and execution of actions described by the words. For example, processing verbally presented actions activates corresponding sectors of the motor system, depending on the effector (face, hand or foot) used in the listened-to action (Floël et al., 2003; Hauk & Pulvermüller, 2004; Buccino et al., 2005). Moreover, in sign language there is a close semantic relationship between the gestures and the function of the object expressed, suggesting that transmodal processes are implicated in pragmatic representations. These studies and numerous observations strongly suggest that the brain areas subtending object-oriented actions are closely related to the brain areas involved with language (e.g., Gentilucci & Dalla Volta, 2008). Recently, Boulanger et al. (2006) showed that verbs related to manual action could perturb reaching movements. Since reaching and grasping are intimately linked (Jeannerod & Biguer, 1981; Frak et al., 2006) manual action verbs could also alter aspects of grasp, such as prehension force. Reaching is a process with a recognized bi-hemispheric activity involving the proximal musculature. Thus, the influence of language on grasp is a highly pertinent subject of study: action with the preferred hand is under control by left cerebral areas, as is the case with language. A novel approach examining the relationship between language and prehension force is presented using a tactile sensing paradigm. Using their preferred hand, subjects seized and held with a precision grasp a 300 g cylinder with an integrated force sensor. With eyes closed and arm extended, subjects listened to words related or not related to a manual action. There was an increase in grasp force when subjects heard words related to manual action only. This increase began at about 100 ms following word presentation, peaked

at 300-400 ms and fell abruptly after 400 ms, signalling a possible inhibition of the motor simulation of the action evoked by the words. These observations reveal the intimate relationship that exists between language and prehension force and show that it is possible to elucidate online new aspects of sensorimotor interaction. They also reveal that there is a continuum between lexical access and motor simulation. Figure 1 shows the grand average of normalized grasp force amplitude of action words (AT) and non-action words (NAT) when they are targets. A paired t-test was done on the data defining both curves. The gray part of the graph, starting at 260 msec and ending at 430 msec, shows where there's a significant difference ($p < 0.05$).

51. Speech perception as a sensorimotor process. Evidence from use-induced motor plasticity. *M. Sato(1), K. Grabski(1), A. Brisebois (2), A. M. Glenberg(3), A. Basirat(1), L. Ménard(2), Luigi Cattaneo(4).* (1) Grenoble Universités, Grenoble, France (2) Université du Québec à Montréal, Montréal, Canada (3) Arizona State University, Tempe, US (4) University of Trento, Mattarello, Italy

In the last years, brain areas involved in the planning and execution of speech gestures have been repeatedly found to be activated in processing speech sounds. From these results, one fundamental question is whether the motor system might partly mediate speech perception through the internal generation of candidate articulatory categorizations. In the present study, we used a new non-invasive behavioral technique based on use-induced activity-dependent plasticity in the orofacial motor system, with the goal of recalibrating action controllers that might be tapped by speech processing. To this aim, participants were required to repeatedly perform 150 lip-protrusion movements (a 'French kiss') for 10 min in order to induce changes in corticomotor control of the orofacial musculature. EMG recordings from the orbicularis oris muscle confirmed that the motor training task was perfectly performed with a constant level of lip activity observed during the whole task. Subsequently, participants performed a speeded identification task on acoustically presented /pa/ and /ta/ CV syllables embedded or not with white noise. As compared to a control task performed at half-an-hour apart without motor training, a decrease of reaction times was observed, together with an increase of bilabial reported syllables. These results provide evidence for a mediating role of the motor system in speech perception. They will be discussed in relation to theories assuming a link between perception and action in the human speech processing system.

52. Somatotopic Motor Systems Are Critical For Category-Specific Semantic Processes. *F. Pulvermüller, Z. Shebani, V. Boulenger, M. Garagnani, O. Hauk, Y. Shtyrov, K. Patterson.* MRC Cognition and Brain Sciences Unit, UK.

Imaging work has shown that the cortical motor system reveals information about the meaning of action words and sentences under processing, even of abstract idioms. When hearing or reading words such as "pick" or "kick", which usually refer, respectively, to hand or foot actions, the precentral areas controlling arm or leg actions light up specifically in fMRI. As somatotopic activation of the motor system reflects the meaning of symbols, this effect has been called semantic somatotopy. Somatotopic semantic motor system activations are rapid, emerging within 200 ms after critical language units become identifiable (MEG, EEG), thus suggesting rapid semantic access. One may however, still ask, whether this activation of the cortical motor system is (a) just associated with the access to, comprehension of, and memory for action words, or in fact (b) critical to these processes? We here review and present data from patients and healthy subjects that clarify this now much debated issue. TMS studies support a critical role of the hand/leg motor cortex for the processing of hand-/leg-related words. In addition, we tested healthy right-handed monolingual native speakers of English in a memory task where action words related to the arm (pick) and leg (kick) had to be read and reproduced after a delay. During the delay, subjects had to rest or perform a complex motor task with either their hands or their feet. We found strong body-part specific interference effects: Foot motor activity led to error enhancement in leg-word memory as compared with arm words. Conversely, the hand-task yielded stronger interference with arm-word memory relative to leg words. These results are discussed in the context of differential involvement of lexical and semantic categories in patients with stroke, Motor Neuron Disease, Parkinson's Disease and, critically, Semantic Dementia. We conclude that body-part specific motor area activation in cortex is crucial for processing and memorizing word categories with concordant body-part specific action meaning. Supported by MRC (UK) and EU.

53. Rehabilitation of verbs retrieval in anomic patients by means of action observation. *L. Craighero (1), A. Cantagallo (2), S. Bonifazi (3), F. Tebaldi (2), C. Biondi (2), M. Coccia (3), L. Provinciali (3), P. Marangolo (3).* (1) University of Ferrara, Ferrara, Italy. (2) Hospital and University of Ferrara, Ferrara, Italy. (3) Department of Neuroscience, Università Politecnica delle Marche, Ancona, Italy.

One common problem associated with aphasia secondary to left hemisphere stroke is word retrieval deficits. The pervasiveness of word-finding difficulties has motivated several theories devoted to the management of the deficit and its effectiveness. Recently, the hypothesis has been advanced that gestures instead of simply accompany speech, participate in language production by increasing the semantic activation of words grounded in sensorimotor features, hence facilitating retrieval of the word form. Based on such assumption, several studies have developed rehabilitation therapies where the use of pantomime reinforced the recovery of verb retrieval. Gestures paired with verbal production resulted in significant naming improvements in some patients with aphasia (Raymer et al, 2006). These positive findings were supported by a series of neurophysiological, brain imaging and behavioural results indicating the existence of a common neural network for language processing and action production/perception, particularly involving Broca's area (Fazio et al., in press). The main aim of the

present study was to verify whether different access modalities to action motor representation differently affect the retrieval of the associated lexical component. To this purpose, a group of aphasic patients with a selective deficit in verbs retrieval were asked to participate to an intensive rehabilitation training including three daily sessions for two consecutive weeks, each session corresponding to a different rehabilitation approach. Each subject was presented a list of 128 transitive and intransitive videotaped actions for three consecutive days: the verbs which the patients could not name in at least two days and for which they always produced an omission were selected. The selected verbs were subdivided into four lists controlled for length and frequency of use. One list was taken as baseline measure and each of the remaining three lists were used for a different rehabilitation procedure: 1) "action observation" 2) "action observation and imitation" 3) "action observation and movement". In all conditions, the patient observed the therapist really executing the action by using appropriate objects. In condition 2, the patient was required to imitate the observed action; while, in condition 3, after observing the action, the patient had to produce an unrelated and meaningless movement. After observing and/or observing and performing the action, the patients were required to produce the corresponding verb. At the end of the treatment and at follow-up (1 week, 1, 2, and 3 months from the end), the patients were asked to rename all the verbs belonging to the three training lists and to the non-trained one. Results suggest a significant improvement in verb retrieval only with the two training methods based on "action observation" and "action observation and imitation". Interestingly, no significant difference were found between the two approaches. Moreover, the follow-up testing revealed a long-term verb recovery which lasted at 3 months from the end of the treatments. These findings confirm the hypothesis that the activation of action representation could play a role in the retrieval of the associated lexical component, supporting the presence of a common neural representation for the motor and the lexical component of the verb.

54. Action Word Understanding Affects Overt Motor Behavior. *M. Gentilucci (1), R. Dakka Volta (1), C. Gianelli (1), G.C. Campione (1). (1) University of Parma, Parma, Italy.*

Is the motor system involved in processing the meaning of action-words? The results of previous neurophysiological and behavioral studies suggested that the comprehension of verbs related to different bodily effectors relies on corresponding somatotopic activations in motor cortex. The present behavioral study aimed at further investigating this issue by determining whether and, in affirmative case, at which stage of motor control, effector-related action verbs influence actions executed with either the same or a different effector. We carried out three behavioral experiments, using go-no go (experiments 1 and 2) and choice (experiment 3) paradigms. In all the experiments we used a semantic decision task with an early delivery of the go signal (during linguistic material processing). In experiments 1 and 2, Italian verbs expressing hand actions, foot actions or an abstract content served as stimuli. At the go signal, participants executed intransitive (experiment 1) or transitive (experiment 2) actions with their right hand in response to the acoustic presentation of action-related verbs and refrained from responding to abstract verbs. In experiment 3 hand-related and foot-related verbs were presented. In one block of trials, participants responded to hand-related and foot-related verbs by lifting their right hand and their right foot by a fixed amount (compatible condition), and in another block of trials they responded to hand-related and foot-related verbs by using their foot and their hand (incompatible condition). Time to response beginning (TRB) and kinematic parameters of the motor responses were measured by means of a motion capture system. In experiments 1 and 2, the action execution was slowed down by hand action-related as compared to foot action-related verbs. In experiment 3, TRB was faster, whereas the action execution was slower in the compatible as compared to the incompatible condition. These data can be interpreted as covert activation of motor programs in response to effector-related action verb presentations, which interfered with actions executed with the same effector. Specifically, it was found that the main kinematic parameter, resulted from the actual action planning, i.e. peak velocity, was affected by the activation of the verb-related motor program. We deduced that only a complete activation of the verb-related motor program could influence peak velocity of the actual action. The facilitation effect observed on TRB (experiment 3) could depend on the fact that before the requested action initiated, the verb-related motor program facilitated the activation of those muscles of the actual action involved also in the verb-related action. Successively, the program of the verb-related motor program competed with the planning of the actual action parameters. In conclusion, the results of the present study showed a complete activation of verb related motor programs, suggesting that the consequences and the goal of the actions were understood. This is in favor of the hypothesis that the relation between verbs and motor areas is properly semantic and it is involved in language comprehension.

55. Verb embodiment in action naming. *D.B. den Ouden (1), C.K. Thompson (1). (1) Northwestern University, Evanston, US.*

Introduction: A body of research suggests that the conceptual representations of actions are partly grounded in motor representations (Pulvermüller, 2005). This research on embodiment has typically considered verb processing, not production. Using fMRI, we investigated whether lexical retrieval of action verbs in overt speech production involves motor areas that are associated with these verbs. Methods: Fifteen right-handed native speakers of English (6 females; mean age 59 (33-69)) named actions based on 2-second video clips, in a 3T scanner. Videos presented actions performed by one male actor in two conditions: 'hand' and 'face' actions. Verb items were matched for argument structure, lexical frequency, length in syllables and length in phonemes, and the videos were matched for visual complexity and showed both face and hand actions in full body view. Stimuli were presented in pseudorandom order (34 trials per condition), with a variable ISI (6-10 seconds). Subjects also performed two motor tasks, for localization of hand (finger tapping) and face motor representations (sliding tongue behind

teeth). Functional activation data analysis was performed with SPM5 software, using the Marsbar tool for ROI analyses. Results: Based on the motor task activations, we determined the peak activation voxels for hand and face action execution for each individual subject on left and right hemisphere primary motor cortex (see Figure 1), sensorimotor, premotor and supplementary motor cortex. We drew 10 mm spheres around these peaks and used the resulting areas as ROIs for the analysis of verb naming. Contrast values for face and hand verbs were entered into a repeated measures 4x2x2x2 ANOVA, with the factors region, ROI type, hemisphere and verb type. This analysis revealed a strong tendency towards a main effect of region ($F(3, 42) = 2.73, p=.056$), driven by less overall activation in sensorimotor cortex than in the premotor and primary motor ROIs. Results also showed a main effect of ROI type ($F(1,14) = 18.45, p<.05$), driven by greater overall activation in the face areas than in the hand areas. Lastly, there was a significant interaction between verb type and ROI type ($F(1,14) = 5.78, p<.05$). This interaction was driven by higher activation of hand verbs in face areas and face verbs in hand areas, as shown in Figure 1. Conclusions: Greater activation in motor and premotor areas than in sensorimotor areas, as well as the greater overall activation in face areas, was to be expected, given the overt nature of the naming task. A surprising result, however, is the strong reversed embodiment effect, where hand action verbs show relatively higher recruitment of face areas than face action verbs, and vice versa. It is possible that the proximity of the face area to the inferior frontal pars opercularis, which has been argued to support motor representations of hand movements (e.g. Rizzolatti & Craighero, 2004), is part of the cause for the observed interaction. References: Pulvermüller, F. (2005, Jul). Brain mechanisms linking language and action. *Nature Reviews Neuroscience*, 6(7), 576-582. Rizzolatti, G., & Craighero, L. (2004). The mirror-neuron system. *Annual Review of Neuroscience*, 27, 169-192.

56. Action knowledge mediates artifact naming. L.J. Buxbaum (1), M.F. Schwartz (1), S.A. Jax (1). (1) Moss Rehabilitation Research Institute, Philadelphia, PA, US

Several accounts of conceptual knowledge posit that sensory and motor attributes play a role in cognitive representations of concrete entities. Still controversial, however, is the degree to which action knowledge associated with objects is critical or even relevant for successful object identification. We previously demonstrated in small groups of subjects that 1) apraxia is associated with relative impairments in conceptual knowledge of artifacts as compared to animals (Buxbaum and Saffran, 2002), and 2) apraxics benefit from strong object affordances (strong association between object structure and action) in learning links between actions and objects (Barde et al., 2007). We performed behavioral and voxel-based lesion symptom mapping (VLSM) analyses in a large sample of left hemisphere stroke patients to assess the relationship between action knowledge and naming of three classes of objects: animals, high affordanced artifacts, and low affordanced artifacts. We assessed three predictions derived from the hypothesis that information about object manipulation is relevant to object identification. First, apraxia scores should bear a stronger relationship to naming of artifacts than animals. Second, patients with apraxia should benefit from strong affordance information in their naming of artifacts. Third, impaired naming of artifacts should be associated with lesions to frontoparietal cortex (i.e., the dorsal stream). Fifty-seven unilateral left hemisphere chronic stroke patients (Mn age 58.5) were recruited from a research registry. Fifty patients had a research quality MRI or CT scan. Participants named 40 animals and 80 artifacts drawn from the Snodgrass and Vanderwart corpus. Forty artifacts were high and 40 low affordanced (matched for frequency and syllables) based on norms published by Magnie et al (2003). Participants also performed pantomimed gesture to the sight of objects and matching of action name to gesture (gesture recognition). Naming of both artifacts and animals were correlated with apraxia scores ($p < .003$); however, stepwise regression indicated that only artifact ($p < .001$) and not animal naming ($p > .05$) made a unique contribution to the prediction of apraxia scores. Naming of high affordanced artifacts (78.0%) was overall reliably superior to low (72.6%), but there was also a significant correlation between an "affordance benefit" score (low – high/ low) and apraxia scores ($p < .004$), indicating that the lower the apraxia scores, the greater the relative superiority of naming of high as compared to low affordanced artifacts. Finally, VLSM analysis (Fig. 1) indicated that lesions to posterior temporal and fronto-parietal cortex significantly predicted naming of artifacts (blue), and lesions to inferior, middle and superior temporal and dorsolateral prefrontal cortex predicted naming of animals (red). These data indicate that 1) deficits in gesture production and recognition are associated more strongly with impaired naming of artifacts than animals, 2) deficits in gesture production and recognition are associated with impaired naming of low-affordanced artifacts, and 3) lesions to neural regions known to mediate meaningful object-related actions are associated with deficits in artifact, but not animal naming. Taken together, these data suggest that artifact identification is modulated by sensorimotor action representations of the dorsal stream.

57. Activation of articulatory information in speech perception. I. Yuen (1), M. Brysbaert (1,2), M. H. Davis(3) & K. Rastle (1). (1) Department of Psychology, Royal Holloway, University of London, Egham, Surrey, UK (2) Department of Experimental Psychology, Ghent University, Ghent, Belgium (3) MRC Cognition and Brain Sciences Unit, Cambridge, UK

Emerging neurophysiological evidence indicates that motor systems are activated during the perception of speech, but whether this activity reflects basic processes underlying speech perception remains a matter of considerable debate. We hypothesized that if articulatory information is activated in speech perception, then this should interfere with a task in which participants are asked to produce a target syllable while listening to a different auditory distractor. The interference effects that we hypothesize constitute distortions of speech production, making the articulatory encoding of auditory distractors disadvantageous to performance. If there is a system for speech perception that is independent of the motor system then participants should be highly motivated to use it in this situation. We used electropalatography (EPG) to measure whether motor information

activated from spoken distractors would yield specific distortions on the articulation of visually-presented target syllables. EPG permits fine-grained analysis of spatio-temporal changes in the contact of the tongue against the roof of the mouth, by sampling contact between the tongue and 62 sites on the palate every 10 ms. Participants produced target syllables beginning with /k/ or /s/ while listening to the same syllables or to incongruent rhyming syllables beginning with /t/. Tongue-palate contact for target productions was measured during the articulatory closure of /k/ and during the frication of /s/. Our prediction was that the production of targets in the incongruent distractor condition would be characterized by greater tongue-palate contact in the first two rows of the palate (representing the alveolar region) than would the production of targets in the congruent distractor condition. Results revealed the predicted sub-categorical 'traces' of the incongruent distractors on target productions, with the incongruent /t/-initial distractors inducing greater alveolar contact in the articulation of /k/ and /s/ than the congruent distractors. Two additional experiments established that (a) the nature of this interference effect is dependent specifically on the articulatory properties of the spoken distractors; and (b) this interference effect arises only when distractors are presented in the auditory modality and does not occur for written distractors. Thus our results provide the first direct behavioural evidence that specific articulatory commands are activated automatically and involuntarily during speech perception. Furthermore, since articulatory interference was not observed with written distractors we suggest that the acoustic-to-articulatory links implicated by our findings are unlikely to have emerged from associative learning processes that are responsible for the acquisition of skilled reading. Although our data suggest that the link between speech perception and motor gestures cannot be explained by simple associative learning processes, we do not claim that this link arises through a specialized linguistic module encapsulated from other perceptual processes. Rather, we interpret our data in the context of a broader emerging framework, whereby the perception of action entails activation of the motor system. Similar effects have already been observed in research using kinematic analyses to investigate reaching and grasping behaviour and it seems likely to us that similar mechanisms are responsible for the links between mechanisms of speech perception and production implied by the present research.

58. Evidence for modality independent conceptual representations: TMS to the left middle temporal gyrus impairs action-verb generation. *M. Bedny, P. Pajtas, R. Saxe, A. Pascual-Leone, A. Caramazza. Harvard Medical School (BIDMC) & MIT, Boston, US.*

What are concepts and how are they neurally instantiated? According to one view, concepts are comprised entirely of sensory-motor experiences that are represented in modality-specific cortices. On this account, the meanings of action verbs are represented in motor and visual-motion brain regions (e.g. Pulvermüller, 2001 TICS). Alternatively, the meanings of action-verbs may be at least in part modality-independent and represented in the left middle temporal gyrus (IMTG). The IMTG is active during verb retrieval for both action verbs, and for verbs that lack visual or motor features (e.g. to believe) (Bedny, et al., 2008 JoN). An outstanding question concerns whether the IMTG is necessary for the retrieval of verb meanings? We used repetitive transcranial magnetic stimulation (TMS) to address this question. Participants saw a concrete noun appear on the screen and generated either an action (verb) or a property (adjective) that went with that noun. Prior to the task, participants either underwent no TMS or 15 minutes of 1Hz TMS to the IMTG or a control region (the left middle frontal gyrus). TMS to the IMTG impaired generation of actions, but not generation of properties. Critically, participants were slower and less accurate at property generation when no TMS was delivered and following TMS to the control region. Therefore worse performance on action verbs in the IMTG condition cannot be attributed to the greater difficulty of action generation. These data suggest that the IMTG is necessary for the retrieval of verb meanings. We hypothesize that the IMTG stores modality-independent conceptual representations of events. More generally, these data suggest that conceptual representations are in part modality-independent.

59. Gestural communication and lateralization of motor excitability: a TMS study. *R. Mottonen (1) H. Farmer (1) K. E. Watkins (1). (1) University of Oxford, Oxford, United Kingdom.*

Viewing another person's hand actions modulates activity in an observer's primary motor (M1) cortex bilaterally. Here, we aimed to find out whether mirroring of bimanual communicative gestures (i.e., signed language) in M1 cortex is left-hemisphere dominant. Right-handed participants with normal hearing and no previous experience of sign language were presented with bimanual symmetric signs of British Sign Language (BSL) in two sessions: (1) A pre-training session, during which the participants were unaware that the presented hand gestures were meaningful signs in BSL. (2) A post-training session that followed a short training during which the participants were informed that some of the gestures were BSL signs and were trained to recognize half of them. In both sessions, single TMS pulses were delivered over the hand area of left and right M1 cortex separately to elicit Motor Evoked Potentials (MEPs) in a contralateral hand muscle (first dorsal interosseous). In the pre-training session, MEPs recorded from left and right hand muscles during presentation of signs were equally modulated relative to a control stimulus (still image), showing no differences in motor excitability between hemispheres. After training, the excitability of the left, but not right, M1 was enhanced ($p < 0.001$) compared to the pre-training session during presentation of both trained and untrained signs. As a result of this enhancement, the modulation of excitability was stronger in the left than right M1 ($p < 0.05$) in the post-training session. This left-lateralization is unlikely to be solely due to extracting linguistic meanings from the signs, since it occurred during mirroring of both untrained and trained (i.e., non-meaningful and meaningful) signs. Furthermore, since identical signs were presented before and after training, the lateralization cannot be explained by their physical characteristics. We, therefore, conclude that the left-lateralization of motor mirroring after training reflects the

participants' awareness of the communicative nature of the gestures.

60. Sleight of hand: The integration of speech and visually degraded hand gestures. *S.D. Kelly, B.C.*

Hansen, and J. Sobo. Department of Psychology, Colgate University, Hamilton, U.S.

Objective. Speech and gesture are believed to form an integrated system in language production (Bernardis & Gentilucci, 2006; Clark, 1996; Kendon, 2004, Kita & Özyürek, 2003; McNeill, 1992, 2005, 2009), and research in cognitive neuroscience has recently extended this view to language comprehension as well (for a review, see Kelly, Manning & Rodak, 2008). However, little is known about what aspects of hand gesture are important for this integration. For example, it is not clear how much visual information is necessary for someone to extract meaning from gestures that accompany speech. In the present study, we used a standard visual degradation technique (e.g., Hansen, Farivar, Thompson, & Hess, 2008) that presented degraded gestures with speech to determine just how much of a signal from low levels of visual cortex is needed for the successful integration of the two modalities during language comprehension. Method. 39 participants watched videos of an actor telling a narrative, with gestures that added complementary visual information to the speech (e.g., saying, "The students were up late last night," while making a drinking gesture). We manipulated the visual clarity of the gestures by filtering the spatial frequency of the videos at five levels of decreasing resolution, resulting in five gesture conditions: non-degraded, 2.5 octaves, 2.0 octaves, 1.5 octaves, and 1.0 octave (most degraded). See Figure 1. Each level of degradation was designed to target an increasingly narrow range of spatial frequencies in the visual cortex (e.g., Henriksson, Nurminen, Hyvarinen, & Vanni, 2008). The task was to answer questions about the verbal content of the narrative after the story concluded. The prediction was that if gestures require a wide range of spatial frequencies in visual areas for successful processing, the integration of gesture and speech (i.e., misremembering that the person in the story said, "The students were up late drinking.") should decrease as the visual signal becomes increasingly degraded. Results. Despite instructions to recall only the spoken portion of the narratives, participants incorporated information from gesture into what they thought they heard, on average, 18% of the time, which was significantly higher than a baseline control (i.e., speech with no gesture: 3%). Interestingly, however, this gesture extraction did not differ across our five levels of degradation, $F(4, 144) = 0.67$, ns. Discussion. Our degradation technique created videos containing different levels of spatial resolution, which activated a decreasingly narrow range of spatial frequencies in the low visual system (i.e., striate cortex). Even in the most highly degraded condition (1.0 Octave, which means only minimal activation in striate cortex), participants were able to extract meaning from gesture and integrate it with speech. This suggests that the integration of gesture and speech operates with only minimal activation of low levels of the visual system and may thus be an automatic neural process (Kelly, Creigh & Bartolotti, in press).

61. Hemodynamic signal fluctuation due to occurrence of cospeech gestures in audiovisual story comprehension. *M. Andric (1), S. L. Small (1).* (1) *The University of Chicago, Chicago, US.*

Objective. Spoken language is very often accompanied by a variety of hand gestures ('cospeech gestures'). These cospeech gestures convey meaningful information to the observer. For example, in verbally explaining how to drive a car, the speaker's cospeech gestures may involve use of his or her hand to represent iconic features relevant to the spoken communication. We have recently characterized some of the brain responses evoked when observing meaningful information from cospeech gestures (Skipper et al., 2009; Dick et al., 2009). In this fMRI investigation, we use a peak and valley analysis to characterize the intensity fluctuations of the hemodynamic signal to occurrence of these cospeech gestures during naturalistic audiovisual story comprehension. Methods. A participant passively watched a 2 min 46 s audiovisual story of a female actor explaining how to drive a car over the course of 4 functional runs, each 6 min 21 s. The video was repeated twice within each run, totaling 8 presentations. Features of the story were coded for the presence of cospeech gestures and no gesture. Images were acquired every 1.5 s in the axial plane at 3-T. The time series was projected to cortical surface representations. Data in the left ventral premotor region was selected and averaged across the 8 presentations for active vertices ($p < .001$). This averaged signal was then entered into a peak and valley analysis (Skipper et al., 2009; Hasson et al., 2004 for a similar method). Results. Peaks in the signal were found using the second derivative of that signal. Each estimation of the peak was fit with a gamma function that was allowed to vary so that the best fit between the actual signal and the summation of the gamma functions could be achieved. 97 % of the variance was explained by the model using this procedure. Half of the full width half maximum (FWHM/2) of a gamma function at a peak was used to determine the search region for finding if an aligned feature of the stimulus (e.g., a cospeech gesture vs. no gesture) elicited that peak. The distance between the FWHM/2 of two temporally adjacent gamma functions is then used to determine a decay or valley in the signal response. Two-way contingency tables (gesture vs. no gesture at each peaks and valleys) show there is a significant difference in the distribution between the two ($p < .05$), with more gestures in valleys than peaks for this region, and similar distributions for no gesture between peaks and valleys. Conclusions. These results suggest that specific regions of the brain show characteristic tuning (i.e., systematic preference) to the presence of cospeech gestures in conditions of naturalistic audiovisual story comprehension. Furthermore, we demonstrate our results using a peak and valley analysis method that fits intensity variations in the time series data and shows that the information in these signal fluctuations can be used to evaluate sensitivity to particular features of the stimuli without requiring a priori decomposition into assumed "events." Dick, A. S., Goldin-Meadow, S., Hasson, U., Skipper, J. I., and Small, S. L. (2009). Co-speech gestures influence neural activity in brain regions associated with processing semantic information. *Human Brain Mapping*. doi:10.1002/hbm.20774. Skipper, J.I., Goldin-Meadow, S., Nusbaum, H. C., and Small, S. L. (2009). Gestures orchestrate brain networks for language understanding. *Current Biology*, 19, 1-7. Hasson, U., Nir, Y., Levy, I.,

Fuhrmann, G., and Malach, R. (2004). Intersubject synchronization of cortical activity during natural vision. *Science*, 303, 1634-1640.

62. The neurobiology of communication in natural settings. *J. I. Skipper (1) and J. D. Zevin (1). (1) Sackler Institute for Developmental Psychobiology, Weill Medical College of Cornell University, New York, US.*

Communication is often believed to be supported by a circumscribed and static set of cortical areas, predominantly in the left hemisphere. The experimental paradigms used to localize hypothetical linguistic functions (e.g., speech sound categorization or word identification), however, do not resemble our everyday experience with language. In order to address the question of how the brain processes language in more natural settings, we developed an approach for analyzing brain data resulting from more ecological stimuli. The steps are: 1) intensive annotation of natural stimuli for purposes of hypothesis testing; 2) locating theoretically distinct functional areas using a blind data driven approach (i.e., probabilistic independent components analysis); 3) finding the functions of those areas using a turnpoints analysis of their associated time course; and 4) finding the functional network relationships between the functionally unique regions with vector autoregressive models. Using this approach, we show that when people watch television containing natural dialogue, much of the brain supports communicative understanding. Specifically, the brain dynamically organizes itself into different cooperative and competitive networks driven by behaviourally relevant contextual information such that this contextual information is used to predict forthcoming communicative content. Speech-associated mouth movements, co-speech gestures, and knowledge and expectations associated with preceding discourse content each drive activity in (different distributions of) the supplementary motor area, pre- and primary motor cortex, pre- and primary somatosensory cortex, and cerebellum. This activity temporally precedes activity in the posterior superior temporal and inferior parietal cortex in the case of mouth movements and middle temporal and anterior superior temporal cortex in the case of co-speech gestures and preceding discourse content. Furthermore, a pattern of response suppression was observed in temporal and parietal cortices consistent with a model in which motor activity is used to predict upcoming speech. These various contextually driven networks work simultaneously (i.e., they cooperate) but are often weighted differently depending on the behavioural relevance of the context (i.e., they compete). Thus, the neurobiology of natural communication is supported by a dynamic and active mechanism that contrasts with most contemporary views of the neurobiology of speech perception and language comprehension as comprising a relatively static and circumscribed set of cortical areas.

63. Age of first-language acquisition affects the neural processing of words: Insights from American Sign Language. *R. I. Mayberry (1), J-K. Chen (2), N. Ferjan (1), D. Klein (2). (1) University of California, San Diego, US. (2) McGill University, Montreal, Canada.*

The brain's classic language areas process all forms of language, spoken, read, or signed, independent of whether it is acquired as a first language (L1) in infancy or a second language (L2) at older ages (1-3). Common to all these brain-language phenomena is language acquisition begun in infancy. Unknown is whether the brain's classic language areas are resilient to perturbations in the onset of first-language acquisition (AoA). To answer this question, we need to investigate circumstances where the timing of post-natal brain growth and L1-AoA are asynchronous. Infants born deaf are isolated from the language spoken around them and further isolated from sign language until they receive special intervention via sign language. In previous work using this population, we found that L1-AoA affects the degree to which the classic language areas are activated during the syntactic processing of American Sign Language, ASL (4). These effects are unique to L1-AoA and uncharacteristic of L2 AoA of either spoken (2) or signed languages (5). Here we ask whether L1-AoA affects lexical processing in ASL. We neuroimaged 21 adult, deaf signers with fMRI as they performed an ASL lexical decision task. Participants decided with a button press whether the second item of prime-target pairs was an ASL sign. Primes were nouns either semantically or phonologically related to ASL targets. Targets were ASL nouns and non-signs; non-sign forms were faithful to ASL phonology. Baseline was watching a still image of a signer. All participants were born profoundly deaf and first began to acquire ASL at ages ranging from infancy to 14 years subsequent to little functional acquisition of spoken language. Length of ASL experience was controlled across participants who had normal nonverbal IQ. Voxel-wise linear regressions on the entire fMRI time series showed effects in anterior language areas and LH posterior visual areas. As L1-AoA increased, hemodynamic activation in BA 44, inferior frontal gyrus (IFG) decreased ($R = -.496$, $p = .018$). Conversely, as age of L1 acquisition increased, hemodynamic activation in BA 18/19, middle occipital gyrus increased ($R = +.545$, $p = .009$); see Figure 1. Performance accuracy did not modulate these effects. Adult deaf signers with infant and early childhood L1-AoA primarily showed activation in LH IFG with less activation in LH middle occipital gyrus relative to baseline. Adults with late L1 acquisition showed the reverse pattern with less activation in LH IFG relative to baseline and primary activation in LH middle occipital gyrus ($F[2,19] = 4.253$, $p = .029$; interaction effect for 3x2 Group by Anterior/Posterior ROI, repeated measures ANOVA). These results show that the onset of L1 acquisition in development has lifelong effects on how the adult brain processes language in lexical and syntactic domains. The degree to which language areas are activated for language processing appears to be contingent upon the temporal relation of brain growth and language acquisition in early life. The results further suggest that language stimulation in early life is critical for the language neural network to fully develop. References 1. Geschwind N (1970) The organization of language and the brain. *Science* 170(3961):940-944. 2. Indefrey P (2006) A meta-analysis of hemodynamic studies on first and second language processing: Which suggested differences can we trust and what do they mean? *Language Learning* 56 279-304. 3. Poizner H, Klima ES, & Bellugi U (1987) What the hands reveal about the brain

(MIT Press, Cambridge, MA). 4. Mayberry RI, Chen J-K, Witcher P, & Klein D (under review) Age of language acquisition affects the functional neural organization of language: Evidence from sign language. 5. Newman AJ, Bavelier D, Corina D, Jezzard P, & Neville HJ (2002) A critical period for right hemisphere recruitment in American Sign Language processing. *Nature Neuroscience* 5:76-80. Figure 1. Mean BOLD response on an ASL lexical decision task for adult, deaf signers grouped by age of first acquisition of ASL as a first language in BA 44 and I8/I9.

64. Events in ASL - from perception to production through linguistic representation: kinematic and fMRI evidence. E. Malaia (1) R. Ranaweera (1) R.B. Wilbur (1) T. Talavage (1). (1) Purdue University, West Lafayette, IN, US.

Sign languages (SLs) as linguistic interfaces of perceptual and non-speech motor behaviors can provide unique insights into neurobiology of language. This study combines a kinematic investigation of ASL predicate production with an fMRI study of their perception to test the Event Visibility Hypothesis (EVH; Wilbur 2003), proposing direct mapping of linguistic structures onto physics of motion for SLs. Predicates contain multifaceted information about semantics of an event, and argument structure. Linguistic theory classifies events according to whether they have an inherent (telic) end-state (fall, awaken), or are homogenous/atelic (read, worship). The EVH reflects the observation that verb signs denoting telic events are morphologically marked by perceptually significant rapid deceleration to a stop, reflecting the end-state. The kinematic study was conducted to test the EVH against motor behavior. 24 telic and 16 atelic signs were chosen, randomized, and presented to 6 native ASL signers who produced them in phrase medial and final positions while wearing a motion capture suit. The right wrist marker tracking hand movement indicated that telic signs had significantly greater peak velocity ($p < .001$), and significantly steeper deceleration ($p < .05$) compared to atelics in both positions, thus supporting the hypothesis that telicity of linguistic event structure is mapped to kinematic variables in sign production. The fMRI study stimuli consisted of the videos recorded in the kinematic study to examine how those differences are processed by the Deaf brain. Subjects were presented with telic and atelic ASL signs in a block paradigm, with non-ASL gesture as a baseline condition. Data were collected at 3 T (GE) using an EPI sequence. Preliminary fixed effects data analysis was effected using SPM5 software, with 3D motion correction, normalization to a standard MNI template and smoothing with a 6mm FWHM Gaussian kernel. Activation clusters ($p < 0.005$, uncorrected for multiple comparisons; threshold cluster size = 5 voxels) were observed in Brodmann Area 46 (centered at MNI [-49 34 23], cluster size = 10 voxels; near Broca's Area), and in left Middle Temporal Gyrus (MTG, centered at MNI [-53 -38 8], cluster size = 9 voxels). The results showing differentiated activation patterns in Inferior Frontal Gyrus for atelic vs. telic ASL predicates demonstrate that predicate's telicity affects language processing, and confirm that kinematic differences in sign production are mapped to linguistic structure of ASL. The relation of the activation cluster in MTG to kinematic and linguistic variables needs further investigation. The combined results of the kinematic and fMRI experiments indicate a role for kinematic features in the perceptual processing of linguistic events in ASL, and in the neural basis of that processing. Considered in combination with event segmentation research (Zacks et al., 2006, 2007), our experiments suggest that perceptual features of events undergo grammaticalization in SLs, and are subsequently processed as linguistic distinctions by the brain. This further confirms the hypothesis that neural correlates of verbs are organized into a two-level system including perceptual features characterizing the event, and its event structure, or combinatory grammatical properties (Kemmerer, 2008).

65. Motor contribution to speech perception. A. D'Ausilio (1), I. Bufalari (1), P. Salmas (2), P. Busan (1), L. Fadiga (1,2). (1) DSBTA - Section of Human Physiology, University of Ferrara, Ferrara, Italy, (2) IIT - The Italian Institute of Technology, Genova, Italy.

Classical models of language localization in the brain consider an antero-posterior distinction between perceptive and productive functions. In the last 15 years, this dichotomy has been weakened by empirical evidence suggesting a more integrated view. A large amount of data is accumulating against the reality of such a strict segregation in speech/language processing. Passive listening to phonemes and syllables activate motor (Fadiga et al., 2002; Watkins et al., 2003; Pulvermüller et al., 2003; Pulvermüller et al., 2006) and premotor areas (Wilson et al., 2004). Interestingly, these activations are somatotopically organized according to the effector recruited in production. However, a distinctive feature of action-perception-theories in general, and in the domain of language more specifically, is that motor areas are considered necessary for perception. All the above mentioned studies are inherently correlational, and it has been argued that in absence of a stringent determination of a causal role played by motor areas in speech perception, no final conclusion can be drawn to support the motor theories of speech perception (Toni et al., 2008). In fact, the mere activation of motor areas during listening to speech might be caused by a corollary cortico-cortical connection that has nothing to do with the process of understanding. Therefore, a possible solution might come from the selective alteration of the neural activity in speech-related motor centers and from the evaluation of effects on perception following such virtual lesions. We recently designed a series of TMS experiments to tackle the causal contribution of motor areas to speech perception. We studied the role of the motor cortex in the discrimination of phonemes produced by the tongue or by the lips (lip-related: [b] and [p]; tongue-related: [d] and [t]). On-line TMS pulses were applied either to the lip or tongue motor representations in precentral cortex, just prior to the presentation of verbal material. Our results show that focal stimulation of the motor cortex facilitates the perception of phonemes concordant with the stimulated region ([d] and [t] with TMS to TongueM1), and inhibits the discrimination of the discordant ones ([b] and [p] in this case). Fadiga et al., *Eur J Neurosci*, 2002. Pulvermüller et al., *Neuroimage*, 2003. Pulvermüller et al., *PNAS*, 2006. Toni et al., *J Physiol - Paris*, 2008. Watkins et al., *Neuropsychologia*, 2003. Wilson et al., *Nat Neurosci*, 2004.

66. A case of a selective conceptual deficit for artifacts and actions. *G. Vannuscorps (1), and A. Pillon (1). (1) Université catholique de Louvain, Louvain-la-Neuve, Belgique.*

Over the past decades, there have been numerous neuropsychological reports of brain damaged individuals who presented a conceptual impairment selectively or disproportionately affecting knowledge related to one category of concrete objects such as living things (animals or/and plant) or nonliving things (artifacts). These reports have provided a rich source of evidence for the theoretical issue of how conceptual knowledge is organized in mind and brain (see for review, Capitani et al., 2003), at least as far as object knowledge is concerned. However, little attention has been paid to how conceptual knowledge of actions may breakdown after brain damage and little is currently known about how the representation and processing of such knowledge is related to the representation and processing of object knowledge. Here we report the single-case study of a brain-damaged individual whose pattern of conceptual impairment provided evidence pertaining to these neglected issues. The patient JJG is a 59-year-old male with a degree in engineering, who suffered a CVA (large left fronto-temporal lesion) two years before the starting of this study. Nine healthy control subjects, matched to the patient for age and education, also participated in the study. The participants were presented several tasks (picture naming, word-picture verification, word-picture matching, semantic property verification) aimed at assessing conceptual knowledge of living things, artifacts, and actions. The three categories of items were matched in concept familiarity, age of acquisition, spoken word frequency, and imageability. The results indicated that, compared to the controls', JJG's performance in every task was significantly impaired for both the artifact and action items whereas it was within the normal range for the living thing items. On the other hand, his performance showed no evidence of a differential impairment between artifact and action items, whatever the task. The patient's performance in additional tasks assessing other domains of conceptual knowledge (famous people and buildings, countries, numerical knowledge) was within the normal range, which allowed us to reject an interpretation of JJG's specific pattern of conceptual impairment in terms of a selective preservation of knowledge of living things. In the patient, brain damage thus appeared to have selectively impaired conceptual knowledge of artifacts and actions by totally sparing knowledge of living things as well as people, geographical, and numerical knowledge. This pattern of conceptual impairment, which has not been reported yet, suggests that conceptual knowledge of actions and artifacts is represented and processed by a common knowledge system. We propose that such system might be a domain-specific system that represents and processes conceptual knowledge required for planning one's own actions and understanding other people's actions, that is, their goals or intentions. Conceptual knowledge of artifacts would be represented by the same system on the assumption that it is build on knowledge of the goal directed actions they serve to realize and for which they were designed (e.g., Asher & Kemler Nelson, 2008). This domain-specific conceptual system would be coupled with the perceptual processes specialized in the analysis of agents' motion and located in the superior temporal sulcus region (Allison et al., 2000). References Allison, T., Puce, A., & McCarthy, G. (2000). Social perception from visual cues: Role of the STS region. *Trends in Cognitive Sciences*, 4, 267-278. Asher, Y.M., & Kemler Nelson, D.G. (2008). Was it designed to do that? Children's focus on intended function in their conceptualization of artifacts. *Cognition*, 106, 474-483. Capitani, E., Laiacona, M., Mahon, B., & Caramazza, A. (2003). What are the facts of semantic category-specific deficits? A critical review of the clinical evidence. *Cognitive Neuropsychology*, 20, 213-261.

67. Distinguishing implicit simulation from explicit motor imagery during language understanding. *Roel M. Willems (1,2), I. Toni (1), P. Hagoort (1,3) and D. Casasanto (3). (1) Donders Institute for Brain Cognition and Behaviour, Nijmegen, The Netherlands (2) Helen Wills Neuroscience institute University of California Berkeley, Berkeley, CA, US (3) Max Planck Institute for Psycholinguistics, Nijmegen, The Netherlands.*

According to embodied theories of language, people understand a verb like throw, at least in part, by mentally simulating throwing. This implicit simulation is often assumed to be similar or identical to motor imagery (e.g. Gallese and Lakoff, 2005). Here we used fMRI to test whether implicit simulations of actions during language understanding involve the same cortical motor regions as explicit motor imagery. If action verb understanding indeed involves some type of implicit motor imagery, one would expect neural correlates for verb reading and explicit motor imagery to overlap. Alternatively, if motor cortex activation during the reading of action verbs does not involve implicit motor imagery, no such overlap is expected. In an event-related fMRI experiment healthy, right-handed participants (n=20) were presented with verbs related to hand actions (e.g. to throw) and non-manual actions (e.g. to kneel). They either read these verbs in a lexical decision task (lexical decision on filler items) or actively imagined performing the actions named by the verbs (imagery task). Data analysis was done in the context of the general linear model with regressors for manual and non-manual verbs. Statistical analysis focussed on comparing MANUAL versus NONMANUAL verbs in each task setting separately, hence the NONMANUAL verbs served as a high-level baseline. Primary motor cortex showed effector-specific activation during imagery, but not during lexical decision. Parts of premotor cortex distinguished manual from non-manual actions during both lexical decision and imagery, but there was no overlap or correlation between regions activated during the two tasks. This was the case when we analyzed the data at the whole brain level, in subject-specific regions of interest, as well as when applying multi-voxel pattern analysis. Put differently, there were parts of premotor cortex which distinguished manual from non-manual verbs in both task, but these activations did not overlap. These dissociations suggest that implicit simulation and explicit imagery cued by action verbs may involve different types of motor representations, and that the construct of 'implicit mental simulation' should be distinguished from 'explicit mental imagery' in embodied theories of language. We suggest that these neural dissociations express the different computational functions of implicit simulation during language comprehension and explicit motor imagery. Whereas explicit

motor imagery is largely reflective, implicit simulation during language comprehension is largely predictive, preparing the language user for future interaction in the world. Reference: Gallese, V., & Lakoff, G. (2005). The brain's concepts: The role of the sensory-motor system in conceptual knowledge. *Cognitive Neuropsychology*, 22(3-4), 455-479.

Prosody

68. A neuroimaging investigation of anger and fear in speech prosody. E. Klepousniotou (1,2), G. B. Pike (2), and M. D. Pell (2). (1) University of Leeds, Leeds, UK (2) McGill University, Montreal, Canada

Behavioural and lesion studies have shown that understanding emotional speech prosody recruits a bilateral and distributed brain network of cortical and subcortical structures. Right hemisphere regions have been shown to play a critical role at certain stages of processing emotion from the voice and this is largely confirmed by fMRI literature which has studied emotional prosody. The fMRI findings imply that different sites of the right STG/STS are preferentially involved at stages of analyzing the acoustic form of vocal emotion expressions. Inferior (bilateral) regions of the frontal lobe (DLPFC, OBF), often greater in the right hemisphere, are also typically activated during tasks of judging emotional prosody. However, the precise operations supported by particular temporal and frontal lobe regions, as well as the relationship between temporal and frontal sites of a presumed prosody network are not yet fully understood. This study aimed to specify further the neural correlates for understanding emotional speech prosody. A block fMRI design was used to investigate the neural substrates involved when listeners: 1) implicitly attend to the emotional meanings of prosody independent of meanings communicated through language; and, 2) interpret different 'basic' emotions in the vocal channel. Semantically-anomalous pseudo-utterances (Suh factor egzulling tuh boshent) were presented which conveyed anger or fear (experimental condition; emotional utterances), or were emotionally neutral (control condition; non-emotional utterances). In all conditions, the stimuli were produced by two male and two female actors, taken from a perceptually-validated inventory. Pseudo-utterances were presented in pairs. Normal control subjects were scanned while listening to each utterance pair and then judging whether the speaker is the same or different (implicit emotion processing). Null trials were also included and served as the baseline control condition. The results revealed bilateral activations involving the pars opercularis (Brodmann's area 44; Broca's area) extending into the frontal operculum, the anterior insula and the superior temporal gyrus for both anger and fear utterances. Bilateral activations were also observed in the supplementary motor area for both anger and fear utterances, as well as in the inferior frontal gyrus, in particular the pars triangularis (Brodmann's area 45) that were greater in the right hemisphere. Importantly, fear utterances revealed additional activation in Brodmann's area 10 in the right hemisphere, pointing to the particular involvement of the rostral orbitofrontal cortex in the processing of fear.

69. Emotions in Word Processing: Functional Localization using Event-Related Brain Potentials. A. Schacht (1) and W. Sommer (2). (1) Humboldt-Universität zu Berlin, Berlin, Germany (2) Humboldt-Universität zu Berlin, Berlin, Germany.

In recent cognitive and neuroscientific research the processing of emotional stimuli is of special interest. Several studies have shown emotional stimuli to involuntarily draw attentional resources, resulting in a preferential and sustained processing. The underlying neural mechanisms are suggested to be reflected in two different components of event-related brain potentials (ERPs): the early posterior negativity (EPN) and the late positive potential (LPC). However, as yet it remains mostly unclear, under which boundary conditions emotional processing depends on the availability of central attentional resources and specific stimulus characteristics. In a series of experiments, we aimed to localize the effects of emotion in visual word processing by recording event-related potentials (ERPs) while participants ($N \geq 20$) performed different tasks on German words. Distinct effects of emotion on ERPs were found which differed with regard to their temporal and spatial distributions and might therefore be related to different stages within the processing stream. In single word processing, the first emotion effect, the EPN, appeared immediately after the differentiation of ERPs to words and pseudowords (lexicality effect; Experiment 1) in lexical decisions. Thus, emotional valence is activated at a post-lexical level. Interestingly, this EPN occurred faster and was more pronounced for positive and negative nouns than for emotional verbs, independent of differences in word frequency. However, word class did not only affect initial emotion effects, but also lexical access as reflected in facilitated lexicality effects to nouns as compared with verbs (Experiment 2). EPN effects showed up earlier, when verbs were embedded into semantic context information and were unaffected by differences in task demands in structural, lexical, semantic decisions (Experiment 3). In a direct comparison, EPN effects appeared later to words than to faces, but showed comparable scalp distributions in both domains, indicating similar underlying brain systems (Experiment 4) to be involved in initial processing of emotional aspects. In contrast, LPC effects were modulated by a variety of different factors and depended on specific task demands. Furthermore, these late emotion effects appeared at comparable latencies but with different scalp distributions to words and faces, indicating contributions of domain-specific brain systems. These results indicate early and late emotion-sensitive ERP components to reflect different mechanisms of emotional processing at early, rather automatic, and late, task-dependent stages, and most importantly, emotional meaning to be activated after lexical access.

70. Neural substrates associated with emotional and linguistic prosodic processing. L. Copeland (1), S. Baum (1), V. Gracco (1, 2). (1) School of Communication Sciences and Disorders, Montreal, Canada. (2) Haskins Laboratory, New

Haven, US.

Background: Speech prosody serves numerous functions, including conveying information regarding meaning as well as emotion or affect. In addition during audiovisual speech processing, prosody interacts with visual cues to enrich and inform the meaning behind the utterance. Although there has been a surge of interest in examining the integration of auditory and visual cues in speech (phonetic) perception^{1,2} and in the perception of emotion^{3,4,5} there has been little direct comparison of the neural substrate for linguistic and affective processing. In the current report, we examine the neural substrate associated with emotional and linguistic prosodic processing in uni- and multi-modal modalities. Methods: Ten healthy volunteers (5 males) were presented with semantically neutral sentences expressing affective or linguistic prosody solely through the use of non-verbal cues (intonation, facial expressions) while undergoing fMRI. The sentences were presented under auditory, visual, as well as audio-visual conditions. The emotional prosody task required participants to identify the emotion of the utterance (happy or angry) while the linguistic prosody task required participants to identify the type of utterance (question or statement). Results: Affective and linguistic processing appear to rely on a common neural substrate for both unisensory and multisensory modalities. The multisensory network included bilateral occipital areas, multiple bilateral areas on the superior temporal gyrus (STG), the supramarginal gyrus, the right superior temporal sulcus (STS), and the pre-supplementary motor area. Within this common network, affective processing resulted in increased areas of activation in the pre-SMA, the left inferior occipital region, the caudomedial and lateral portions of the posterior STG (pSTG), as well as an area around the right STS. In contrast, linguistic processing resulted in increases in activation on the right lateral pSTG, left middle STG, the left superior temporal plane and the right inferior occipital region. Conclusions: The model of speech prosody processing that emerges is, for the most part, one of overlapping bilateral activation for affective and linguistic prosody, with the strength of activation modulated by task demands and modality of presentation. References 1. Calvert, G. A. & Campbell, R. (2003). *Journal of Cognitive Neuroscience*, 15, 57-70. 2. Calvert, G. A., Campbell, R. & Rammer, M. J. (2000). *Current Biology*, 10, 649-657. 3. Ethofer, T., Pourtois, G. & Wildgruber, D. (2006). *Progress in Brain Research*, 156, 345-361. 4. Kreifelts, B., Ethofer, T., Grodd, W, Erb, M. & Wildgruber, D. (2007). *NeuroImage*, 37, 1445-1456. 5. Pourtois, G., de Gelder, B., Bol, A. & Crommelinck, M. (2005). *Cortex*, 41, 49-59.

71. ERP correlates of word learning in infants and toddlers: The impact of affective prosody. M. Friedrich, D. Marinos, M. Schmitz, G. Klann-Delius, A.D. Friederici. *Free University Berlin, Berlin, Germany.*

Word learning includes the acquisition of phonological forms, the extraction of relevant meanings, and the mapping between word form and word meaning memory representations. Behavioral studies have suggested that initial word learning during infancy requires very frequent exposure to a word form and its referent, whereas shortly after the first birthday infants become able to fast learn a novel word for a novel meaning. At the neurophysiological level, existent lexical-semantic knowledge in infants and toddlers affects their ERP components reflecting acoustic-phonological and semantic word processing stages. Two ERP priming effects are observed when presenting words together with pictures: the N200-500 word form priming effect and the N400 semantic priming effect. Recently it has been shown that the experimentally induced fast acquisition of novel object-word mappings in 14-month-olds is accompanied by the emergence of these two ERP priming effects (Friedrich & Friederici, 2008). The present study focuses on the role of emotion in early development, in particular on the impact of affective prosody on the fast learning and remembering of novel object-word mappings. Here we combined ERP and behavioral methods. During the ERP training phase, one- to two-year-olds children were repeatedly presented with pairs of novel objects and novel words. Half of the words were spoken neutrally; the other half were spoken with pronounced positive (happy) prosody. During two subsequent behavioral test phases, each four different objects were shown after naming a particular object. The child's first pointing or grasping was taken as behavioral response. The ERPs of the training phase show learning effects for both neutral and positive prosody conditions, although different to some degree, which indicates that different neural resources are utilized, and different neural mechanisms are involved in the acquisition of either positively or neutrally spoken object labels. The behavioral results indicate a higher performance for positively than neutrally spoken words in the test phase half to one hour after training, but a higher performance for neutrally than positively spoken words in the test phase one day later. The results indicate that positive affective prosody facilitates the encoding and short lasting memory formation of object-word mappings, but it does not facilitate the long-term memory consolidation of these mappings. This might be caused by an interference of emotional (affective valence to object) mapping with lexical (word to object) mapping during the process of memory consolidation.

72. The neural substrates of prosody comprehension: evidence from a functional magnetic resonance imaging study. I. Deschamps (1) I. Itzhak (1) E. Klepousniotou (1) S. Baum (1) V. Gracco (1) (2). (1) McGill University, Montréal, Canada (2) Haskins Laboratories, New Haven, US

The present study examined the processing of prosodic information to differentiate declarative from interrogative sentences using functional magnetic resonance imaging. We were interested in whether judgments about the illocutionary force (intent) of a sentence engage distinct neural systems than judgments about the acoustic properties of a sentence (changes in fundamental frequency (F0)). In order to compare the acoustic processing of intonation to the linguistic assignment of illocutionary force, we used the same sentence "He wants to leave now" with different word-final intonation contours in two different tasks. The F0 of the final word (e.g. now) was linearly increased to a level equivalent to that of its question counterpart in eight intermediate steps. Because a single sentence was used and the F0 independently manipulated, no changes

in duration or amplitude were imposed on the stimuli. Based on previous behavioural results, the two endpoint stimuli, labelled S1 (unambiguous statement intonation) and S10 (unambiguous question intonation) and two ambiguous stimuli (labelled S4 and S7) were chosen from the continuum for presentation in both tasks. Subjects listened to the same sentence and they identified either the direction of the contour (rising/falling) or made a declarative/interrogative judgment. Using a single sentence eliminated any semantic or lexical cues for the attribution of intent. It was reasoned that brain areas sensitive to the intent of the sentence would show a difference in the magnitude of neural activation for the between category contrasts (than they would in a within contrast), even though the degree of acoustic change was kept constant. The primary findings of the whole brain analysis, as well as the ROI analyses, suggest that making a judgment about the intonation pattern (F0) of a sentence and making a judgement about the illocutionary force of a sentence engage overlapping bilateral neural networks, primarily involving temporal and frontal regions, as well as the basal ganglia and the cerebellum. In all these common areas, however, the magnitude of the BOLD signal was stronger for Question/Statement judgments than the Rising/Falling judgments. The neural response to ambiguous stimuli engaged activation in the IFG. In sum, the findings of the present investigation identified a largely overlapping bilateral cortical-subcortical network involved in both the processing of the acoustic-prosodic cues to sentence modality (in this case, rising vs. falling sentence-terminal fundamental frequency) and the attribution of illocutionary meaning (question vs. statement). There is no evidence that the processing of illocutionary force is distinct from the processing of acoustic changes that distinguish a statement from a question although there were areas that were only active in the attribution of illocutionary force.

73. An incremental processing of lexical accent: An ERP study in Japanese. K. Ito (1,2), R. Horie (3,2), H. Oishi (2), M. Hasegawa (2) and R. Mazuka (2). (1) Ohio State University, Columbus, US. (2) RIKEN Brain Science Institute, Wako, Japan. (3) RIKEN Advanced Science Institute, Wako, Japan.

Past studies suggest that the impact of lexical prosody on word recognition may be language-specific [1-3]. Japanese has a lexical pitch accent realized as a sharp fall in pitch, and listeners are known to be sensitive to word-initial lexical pitch patterns [4, 5]. However, the function of the lexical accent has not been sufficiently described and qualitatively distinguished from that of segmental information in any existing model of word recognition. Furthermore, no study has explored how an accentual anomaly is processed at a later stage of word recognition. To achieve a full-fledged description of the role of lexical prosody, processing of lexical accent must be examined at various points in words. The present study examined the electrophysiological responses to both segmental and accentual anomalies at various points in words using an object-naming verification task. Participants saw a photo of a common object (e.g., a bottle of mayonnaise) and verified a following utterance that named the object (e.g., Kore-wa mayone'ezu desu. "This is mayonnaise." The apostrophe indicates the lexical accent on the preceding mora /ne/). The target words were either (1) matched with the object's name, (2) mismatched in the vowel of the accented mora (mayona'azu), (3) mismatched in the consonant of the accented mora (mayome'ezu), (4) mismatched in the accent location (mayo'neezu) or (5) mismatched in the semantics (kecha'ppu "ketchup"). In (4), the lexical accent was shifted either to the left or to the right, exhibiting the distinctive pitch fall either earlier or later than expected. The ERP responses were collected from 31 right-handed native speakers of Tokyo Japanese using 29 active-electrodes. Each session included 40 trials in each of the five conditions and 80 filler trials. The semantic mismatch trials elicited clear N400 responses, verifying the adequacy of the experimental paradigm. A negative-positive complex was identified bilaterally for both the vowel and the consonant mismatches and also for the early accentual shifts (Fig1). For the later accentual shifts, only an extended positivity was elicited. The early negativity of the biphasic component is considered a Phonological Mismatch Negativity that reflects the responses to phonological violation –whether it is segmental or supra-segmental. Later positivity seems to relate to the Late Positive Component that reflects the processes of lexical retrieval. Waveform correlation analyses identified the F0 peak as the most reliable alignment reference for the elicitation of the ERP responses to the accentual mismatch, among other phonological and phonetic references. These results demonstrate that lexical pitch accent and segments are processed similarly in Japanese, but its weight in word recognition may vary according to the timing of the processing. While early accentual cues may constrain lexical access, later accentual cues may be evaluated incrementally against the segmental information at hand. That the ERP responses were best aligned by F0 peak also suggests that the processing of lexical prosody is fundamentally bottom-up. Were these novel findings attested crosslinguistically, models of word recognition would achieve a better specification of the role of lexical prosody. References: [1] Cutler, A. (1986). Forbear is a homophone: lexical prosody does not constrain lexical access. *Language and Speech*, 29(3), 201-220. [2] Van Donselaar, W. A., & Cutler, A. (1997). Exploitation of stress information in spoken-word recognition in Dutch. *Journal of the Acoustical Society of America*, 102, 3136-3136. [3] Soto-Faraco, S., Sebastián-Gallés, N., & Cutler, A. (2001). Segmental and suprasegmental mismatch in lexical access. *Journal of Memory and Language*, 45412-432. [4] Cutler, A., & Otake, T. (1999). Pitch accent in spoken-word recognition in Japanese. *Journal of Acoustical Society of America*, 105(3), 1877-1888. [5] Sekiguchi, T. (2006). Effects of lexical prosody and word familiarity on lexical access of spoken Japanese words, *Journal of Psycholinguistic Research*, 35, 369-384

74. Neural Integration of Lexical and Indexical Information in Spoken Language Processing. B. Chandrasekaran (1), Chan. A.H.D (1), and Wong. P.C.M (1). (1) Communication Neural Systems Research Group, Northwestern University, Evanston, US.

Introduction Speech carries information related to content, i.e. (e.g. words), and information related to the speaker called indexical information (e.g. age, sex, emotional status). According to exemplar models of speech processing, lexical features

and indexical features are represented integrally, leading to the influence of lexical processing by indexical information (Goldinger, 1998). Previous studies have examined the nature of lexical representation in the brain without varying indexical information (Gagnepain et al., 2008). Word-specific neural adaptation has been observed in the left posterior MTG, a region that has been described as the lexical interface that houses long-term stored representation of words (Hickok and Poeppel, 2007). Although studies have implicated this region in word processing, the nature of neural code involved in lexical representation is unclear (Lau et al., 2008). In the current study, we used fMRI adaptation to examine the extent to which indexical information influences neural representation of lexical information.

Methods Thirteen English-speaking young adults performed an amplitude judgment task in six listening conditions while their BOLD response was measured using an fMRI sparse-sample design (Belin et al. 2000). Each trial composes of a set of four words or nonwords, spoken by a single-talker or multiple talkers. In the primed conditions, the same talker repeated four words or nonwords. In the unprimed conditions, the same talker repeated four different words or nonwords. Finally, in the unprimed voice conditions, multiple talkers repeated the same four words or nonwords. Two separate mixed ANOVA models with two fixed factors (and subject as random factor) were used to analyze the data. In one model, the two factors were lexicality (i.e. words vs. nonwords), and prime status (primed vs. unprimed). In the second model, the two factors were lexicality (words vs. nonwords) and indexicality (multi-talker vs. single-talker). Results. A significant lexicality by prime status interaction effect ($p < 0.05$, corrected) was found in a number of regions including bilateral STG, and the left MTG. Based on the apriori hypothesis, ROI analyses conducted on the left posterior MTG revealed repetition suppression for words (i.e. reduced BOLD responses in the primed condition, relative to the unprimed condition), and an enhancement for nonwords (i.e. enhanced BOLD responses in the primed condition, relative to the unprimed condition). The second ANOVA (lexicality by indexicality) revealed a significant interaction effect exclusively in the left posterior MTG ($p < 0.05$, corrected). Post-hoc t-tests revealed reduced BOLD response for the single-talker condition, relative to the multi-talker condition, only for words.

Conclusions. Using fMRI adaptation as a neural index, we show significant lexicality by priming effect in the left posterior MTG, suggesting that neural responses in this region show word-specificity. The left posterior MTG has been argued to engage in abstract lexical processing. In our experiment however, responses in this region show a significant lexicality by indexicality interaction effect. Neural processing of words in this region is thus modulated by change in indexical information. These results thus provide support for exemplar models of speech processing that posit functional integrality in the representation of object features.

75. Closure Positive Shifts (CPS) as reflecting on-line segmentation of prosodic rhythm-groups in speech. A. C. Gilbert (1) B. Jemel (2) V. J. Boucher (3). (1) *Laboratoire de sciences phonétiques, Université de Montréal, Montréal, Canada.* (2) *Laboratoire de Recherche en Neurosciences et Électrophysiologie Cognitive, Hôpital Rivière-des-Prairies, Montréal, Canada* (3) *Laboratoire de sciences phonétiques, Université de Montréal, Montréal, Canada.*

Marks of structural prosody in speech as opposed to lexical marks like “word-stress” are not coded in language but appear universally. These marks associated with rhythm and intonation groups (RGs and IGs) also occur spontaneously in the oral recall of digits or non-sense series, which generally suggests that structural prosodic groupings can be linked to processes of short term memory. In research using ERPs, it has been found that IGs in meaningful utterances as well as in meaningless series evoke a “closure positive shift” (CPS) (Steinhauer 1999, Pannekamp 2005). The present study adopts the view that CPS reflects instead the effects of RGs. Grouping effects on recall are well documented. What is less recognized is that such grouping obeying to similar constraints also appear in speech (Boucher, 2006), suggesting that CPS may capture an online segmentation relating to short-term memory processes. To illustrate that CPS is specifically evoked by RGs, two experiments were devised where RGs were manipulated independently from IGs. Experiment 1 involved meaningful French sentences, whereas Experiment 2 used meaningless series of syllables. For both types of stimuli, RGs were placed within an IG. The stimuli were elaborated from naturally spoken material using a pacer technique. In this technique, a native speaker utters given contexts while listening to a pacer consisting of pure tone beats bearing the desired rhythm and intonation changes. All 400 target stimuli were constructed (200 meaningless series of syllables, 200 meaningful utterances) with similar RGs and IGs. Additionally, 480 filler stimuli were constructed to vary rhythm, intonation and syntactic content. The two sets of stimuli were presented separately and in random blocks. Subjects’ task consisted of listening to each stimuli and determining if a subsequent prompt was part of a presented utterance or series. Continuous EEG was recorded using 59 scalp electrodes (DC-100Hz, 1000 Hz sampling rate). An averaged left-right earlobe reference was applied to all scalp electrodes. After artifact rejection and eye-blink correction, ERPs were averaged with respect to the P-center of the first syllable for both meaningful sentences (experiment 1) and meaningless series (experiment 2). In all, 15 subjects will participate in the test. At present, the results of one subject show that, even within meaningful utterances, CPS is specifically evoked by RGs. These results bear two implications. First, previous studies showing that CPS is evoked by IGs did not control for RGs. Our present experiment will show that CPS can be specifically evoked by RGs. Second, given that CPS reflects the processing of RGs that are compatible with patterns found in speech and recall, the findings support a perspective of a link between CPS and a process of online segmentation of heard verbal material likely reflecting a notion of focus of attention.

76. Signal processing of speech and prosody in primary progressive aphasia. Jonathan D. Rohrer (1), Jane E Warren (2), Martin N Rossor (1), Jason D Warren (1). (1) *Dementia Research Centre, UCL Institute of Neurology, London, UK,* (2) *MRC Clinical Sciences Centre, Imperial College London, UK.*

The progressive aphasias (PPA) are canonical ‘language-based dementias’ overlapping the frontotemporal lobar degeneration

spectrum. While the neurolinguistic and structural neuroanatomical correlates of PPA are currently a major research focus, less attention has been paid to functional changes in neural networks that process speech signals in these disorders. We addressed this issue using 3T fMRI in a cohort of patients with PPA diagnosed according to current consensus criteria in comparison to healthy older control subjects. Subjects were scanned while listening to short sentences derived from the BKB lists under six conditions: i) passive listening to natural speech, ii) passive listening to flattened speech (speech with natural prosodic contours removed), iii) passive listening to rotated speech (a baseline stimulus of comparable acoustic complexity to speech but unintelligible); iv) repetition of natural speech, v) repetition of flattened speech; and vi) rest (silence). Compared with healthy controls, patients with PPA showed reduced engagement of distributed frontal language areas and altered modulation of activity in speech-related areas under the prosodic manipulation. The findings provide evidence for functional alterations in speech signal processing and speech network dynamics in PPA.

Cognitive and Executive Functions

77. Early automaticity vs. late attention control in neural language processing: neurophysiological evidence. *Y. Shtyrov (1), T. Kujala (2), F. Pulvermuller (1).* (1) MRC Cognition and Brain Sciences Unit, Cambridge, UK (2) Cognitive Brain Research Unit, University of Helsinki, Finland.

It has been a matter of debate to what extent the distinctively human capacity to process language draws on attentional resources or whether some stages or types of this processing may be automatic. To address this question, we modulated the level of attention on the auditory input, and recorded event-related potentials elicited by spoken linguistic stimuli in two experiments. In Experiment 1, the responses were elicited by acoustically matched words and pseudowords. Under non-attend conditions (subjects distracted by watching a video), the word-elicited response (peaking at ~120 ms) was larger than that to pseudowords, confirming early activation of lexical memory traces, which we reported previously. These early responses to words seemed unchanged by attentional variation, which we explain by robustness of pre-existing memory networks for words whose strong internal connections guarantee rapid full-scale activation irrespective of the attentional resources available. At the same time, early pseudoword response was modulated significantly by attention. Later on (after ~150 ms), attention modulated the response dynamics which included a prominent positive deflection at ~230 ms and a second negativity at ~370 ms for all stimuli. In Experiment 2, syntactic stimuli were played to the right ear, while the subjects were either passively distracted (by a video) or had a demanding distraction task of tracking non-speech auditory events in the contralateral ear. Syntactic agreement violations produced an early (starting 80 ms) response, more negative going than that to correct phrases, which is also known from the earlier studies. However, neither of the responses were modulated by the attention withdrawal at their earliest stages, up to 140 ms. Later, attention variation significantly modified the phrase-elicited ERPs throughout the remaining epoch (~150-400 ms). The two studies used speakers of different languages (Finnish in Experiment 1 vs. English in Experiment 2), different linguistic contrasts (lexical vs. syntactic), different techniques and directions of attention modulation (closer attention to the stimuli vs strong concurrent distraction in the same modality). However, they indicated remarkably similar temporal periods in language perception. The earliest stages of linguistic processing (here until 140 ms) appear to be immune to attentional demands and may thus be automatic, while top-down attention-modulated effects on both lexical and syntactic processing accumulate later (after 150-200 ms). Language automaticity therefore seems to apply to different types of information, but is at the same time limited to the very first stages of linguistic processing. Later steps are affected by attention allocation regardless of the exact information type. These later steps, which possibly reflect a more in-depth, secondary processing or re-analysis and repair of incoming speech, are thus dependant on the amount of resources allocated to language. Full processing of spoken language is therefore not possible without allocating attentional resources to it; this allocation in itself may be triggered by the early automatic stages in the first place.

78. The role of awareness in semantic and syntactic processing: an ERP attentional blink study. *L. Batterink (1), C. Kams (1), Y. Yamada (1), E. Pakulak (1), H. Neville (1).* (1) University of Oregon, Eugene, US

The role that automatic and controlled processes play in semantic and syntactic processing is not well understood. In semantic priming studies, there is a lingering debate about whether the N400, an ERP component elicited by unexpected linguistic stimuli, reflects an automatic or controlled, post-lexical process. Syntactic priming, specifically word category priming, has been even less well characterized. We used an attentional blink (AB) paradigm, which can be used to manipulate the role of awareness in the processing of target words, to assess automaticity in semantic and syntactic processing. We compared ERP responses to targets occurring within the AB period to targets occurring outside the AB period, and compared ERPs to correctly-reported versus missed targets. In the semantic block, primes and targets were either semantically related or unrelated, and in the syntactic block, primes and targets formed either syntactically congruent or incongruent phrases. In the semantic block, targets occurring both within and outside the AB period elicited an N400. However, N400 amplitude was significantly reduced during the AB period, and missed targets did not elicit an N400. In the syntactic block, a late negative syntactic congruency effect was elicited by targets occurring outside the AB period while targets occurring within the AB period showed no effect of congruency. Semantic results support the argument that the N400 is primarily an index of a controlled, post-lexical process. Syntactic findings suggest that the brain response to some syntactic violations depends on awareness and availability of attentional resources.

79. fMRI of grouping effects in verbal short term memory. K. Kalm (1,2), M. H. Davis (1), and D. Norris (1). (1) Medical Research Council Brain & Cognition Sciences Unit, Cambridge, UK (2) University of Cambridge, Cambridge, UK.

Dividing auditory sequence into groups, or imposing rhythmic, tonal or spatial structure during presentation, improves recall performance (1). Several competing models have been proposed to account for these effects (2,3), but very little is known about the neural basis of grouping. The present study used functional magnetic resonance imaging (fMRI) to compare the processing of grouped and ungrouped lists of subspan (six letters) and supraspan (nine letters) length in an immediate serial recall task. After presentation of each list, participants either immediately recalled the list verbally or simply waited for the next presentation, as indicated by a visually presented recall cue. Auditory presentation and recall was used in order to maximize the potential grouping effects. Participants spoken responses were recorded for behavioural analysis, which showed a significant interaction for grouping ($F=10.7$, $p<.002$) and a main effect for length ($F=588$, $p<.001$). Analysis of activation revealed an extensive pre-motor and pre-frontal network which was significantly less active during encoding when short term memory span was exceeded. Only primary auditory areas showed increase in activation for the supraspan phase. Comparison of activation of grouped and ungrouped lists revealed that bilateral anterior-superior temporal areas showed reduced activation for grouped stimuli throughout the encoding phase. Bilateral superior temporal planum showed less activation for grouped stimuli during the subspan phase, while supramarginal and inferior parietal areas were more active for grouped lists during the supraspan phase. Regions of interest sensitive to grouping were used as regressors to predict each participant's behavioural grouping effects. Left supramarginal gyrus showed reliable positive correlation with positional recall performance ($r=.41$, $p<.05$) of supraspan grouped lists, while bilateral antero-superior temporal gyrus showed negative correlation (left STG: $r=-.49$, $p<.05$). The results suggest that subspan encoding of verbal stimuli is substantially different from supraspan encoding. Success in recalling items from grouped lists is correlated with reduced activity in superior temporal areas and increased activity in supramarginal and inferior-parietal regions. Previous research has associated antero-superior temporal regions with auditory perceptual processing (4) and shown parietal areas to be involved in processing of chunked stimuli (5). Thus neural signatures of grouping seem to reflect more structured processing in parietal areas instead of reliance on perceptual-auditory processing in temporal regions. 1) Ryan J (1969) Grouping and short-term memory: different means and patterns of grouping. *Q J Exp Psychol* 21:137-147. 2) Burgess N, Hitch GJ (2006) A revised model of short-term memory and long-term learning of verbal sequences. *Journal of Memory and Language* 55:627-652. 3) Page MP, Norris D (1998) The primacy model: a new model of immediate serial recall. *Psychol Rev* 105:761-781. 4) Ojemann G, Schoenfeld-McNeill J, Corina D (2009). The roles of human lateral temporal cortical neuronal activity in recent verbal memory encoding. *Cerebral Cortex*, 19(1), 197-205. 5) Bor D, Duncan J, Wiseman RJ, Owen AM (2003) Encoding strategies dissociate prefrontal activity from working memory demand. *Neuron*, Vol. 37, 361–367.

80. Converging evidence for decision-making in successful communication. C. McMillan (1), D. Gunawardena (1), N. Ryant (2), R. Clark (2), & M. Grossman (1). (1) University of Pennsylvania Medical Center, Philadelphia, US. (2) University of Pennsylvania, Philadelphia, US.

Semantic ambiguities, such as homophones, create a challenge for successful communication. We propose that individuals use strategic decision-making to minimize ambiguity during communication. Using a game-theoretic framework we argue for a probability mechanism to calculate the likelihood a word's meaning (Is "pen" likely to refer to a writing instrument or animal cage?) and a value mechanism which calculates the risk associated with choosing an interpretation (Will I be understood?). In Experiment 1, a BOLD fMRI study, healthy young adults ($n=16$) were administered a sentence completion task. Participants were presented with a context-neutral sentence (e.g., Tony has a job) or a context-biasing sentence (dominant: "Tony has ink"; subordinate: "Tony has pigs") followed by a completion sentence ("He needed a ___"). They were instructed to complete the sentence with one of two choices: a homophone (e.g., "pen") or an alternative (e.g., "cage"). In addition to manipulating the context of the sentences we also manipulated the Balance of homophones which refers to the probability of a given meaning (e.g., pen is biased toward one meaning; pitcher is equally biased toward two meanings). Individuals chose fewer homophones in the neutral context as the balance decreased ($Z= -5.22$, $p<.0001$) suggesting they use probability to determine whether or not to minimize ambiguity. The fMRI analysis revealed dorsolateral prefrontal cortex (dlPFC, BA 45/47) activation in the neutral-subordinate context, consistent with literature implicating dlPFC for probability calculations. In the subordinate context individuals chose fewer homophones as the balance increased suggesting they take into account the risk of producing a homophone when it is more likely to be misinterpreted ($Z= 2.62$, $p<.01$). fMRI revealed ventromedial prefrontal cortex (vmPFC; BA 10/11) activation in the subordinate-neutral context, consistent with literature implicating vmPFC in tasks which involve value calculations. In Experiment 2 we used the same experimental method and demonstrated that behavioral-variant frontotemporal dementia (bvFTD; $n=10$) patients, who have disease in dlPFC and vmPFC, minimize ambiguity significantly less than healthy seniors ($n=18$) in the neutral context ($\chi^2=3.99$, $p<0.05$). This suggests that bvFTD patients have difficulty evaluating the probability and value associated with minimizing ambiguity due to frontal cortex disease. These two experiments provide converging evidence for the role of a decision making network in communication. Specifically, we argue that dlPFC supports a probabilistic mechanism and vmPFC supports a value mechanism associated with communicating successfully.

81. ECoG recordings during word repetition and verbal memory tasks: Gamma activation in frontal executive language areas. J. McKee (1), B. Parris (1), M. A. Kohrman (1) J. Ebersole (1), S. Hawes-Ebersole (1), R. Penn (1) D.L. Frim (1) and V.L. Towle (1). (1) The University of Chicago, Chicago, US.

Objective: Most patients with intractable epilepsy suffer from verbal memory deficits, which are often worse after surgical treatment. A better understanding of those areas that contribute to verbal memory storage and retrieval processes is needed, along with development of techniques to identify them prior to surgical resection. The purpose of this study is to determine which areas of the brain are activated during verbal memory tasks by analyzing EEG recordings from normal subjects and electrocorticographic (ECoG) recordings from patients with chronic subdural electrodes implanted as part of their surgical work-up for intractable epilepsy. Subjects: ECoG recordings from eight epilepsy patients admitted to the epilepsy center at the University of Chicago for medically intractable seizures were studied. Grids containing 88-162 subdural electrodes chronically implanted over the frontal, parietal, and temporal lobes were placed according to the needs of the patient. The patient findings were compared to EEG and behavioral studies obtained from 14 normal volunteer subjects. Methods: Participants performed short-term and long-term verbal memory tasks using auditory presentation of words presented through a free-field speaker. For the short-term memory task the participants heard 6 words over 6 sec, followed by a probe word. They then verbally indicated whether the probe word was one of the original 6 words. Ten trials were mixed with 10 control trials. For the long-term verbal memory task the subjects listened to a list of 10 words, which they were asked to memorize. Directly following the words, the participants were distracted from rehearsal by a 1 min series of simple arithmetic problems. The subjects were then asked to state all the words from the list they could recall within 1 min. The subjects then listened to a list of 20 words, and were required to state whether each word was in the original list. Three trials of this condition were conducted. Results: The normal subjects emitted an event-related potential during the memory task which was different for new and old words. The late component at 600 msec, associated with memory retrieval for studied words was greater in amplitude ($p < 0.01$) and shorter in latency ($p < 0.01$) compared to novel probe words. The patients emitted transient bursts of high gamma activity (70-100 Hz) from motor and language areas, as well as frontal and parietal areas outside of these regions during memory storage (Figure 1). Conclusions: Preliminary EEG recordings from a small series of normal subjects and chronic subdural ECoG recordings from epilepsy patients reveal frontal lobe cortical areas that are active during short-term and long-term memory tasks. The identification of these areas may be useful for the planning of cortical resections for the treatment of intractable epilepsy. Discussion: The ability to identify the location of cortical areas that are involved in verbal memory storage and retrieval processes and their temporal dynamics may provide a better understanding of the neural substrates of language and verbal memory processes. Figure 1: Frontal and parietal ECoG activation recorded from a left temporal lobectomy patient during short-term memory (STM) storage.

82. The role of syntactic cueing in early tool concepts. E. Zinchenko (1), J. Snedeker (2). (1) University of Chicago, Chicago, US (2) Harvard University, Boston, US.

We addressed the role of language and motor experience in early tool concepts, using a behavioral paradigm to address a dilemma arising from neuroscience. Recent brain imaging studies implicate that premotor and parietal areas are active in language tasks involving tool concepts, such as single-word reading, lexical decision, and word generation. These findings suggest that motion-processing regions are also involved in representing the meaning of tool terms (Chao, Haxby & Martin, 1999; Kiefer, 2005; Vitali, Abutalebi, Tettamanti, Rowe, Scifo, Fazio et al., 2005). However, these brain imaging data are consistent with three different theories of conceptual content: (1) strong embodied cognition view which argues that motor information is central to tool terms, (2) extended cognition view which argues that motor information is partially involved in tool concepts, and (2) abstract cognition view which argues that motor information is peripheral to tool concepts and that tool terms are fixed by abstract information about the tool's function. We used a word extension task to explore whether conceptual content of tool terms is motoric at an early age. If motor information is central to tool concepts it should be the basis of children's categorization tasks. Children were introduced to a novel tool ("a dax") that had a novel motor movement and novel function. Then they were shown two test tools, one which shared same function and one which shared the same movement. After children had some motor experience with them, they were asked which one is "another dax". Three-year-olds, 5-year-olds and adults categorized novel tools according to a shared function (71% of choices, 75% and 93% respectively, all p 's < 0.001), suggesting that at least by 3 years of age, abstract information overrules motor experience in tool concepts. Children continued to categorize novel tools based on shared functions even when any perceptual information about the function was invisible and non-perceptual (78% for 3-year-olds and 82% for 5-year-olds, all p 's < 0.001). We then explored the role of language in children's thinking about novel tools. When they were given minimal descriptive information about the tools ("it does this and makes that"), 5-year-olds continued to categorize tools based on shared function, while 3-year-olds were at chance. However, when children were given minimal syntactic cueing about the tools' function ("it does this *to* make that"), 3-year-olds were able to categorize tools based on shared functions. In sum, by three years of age children's tool concepts are abstract even when information about tools' function is not perceptually available and despite having motor experience with tools. In the absence of rich linguistic description, minimal syntactic cueing supports children's abstract representation of tool terms. These findings are contrary to the hypothesis of the embodied cognition view.

83. The subcortical role of language processing; an fMRI study. D. Ketteler (1), S. Ketteler (2), R. Vohn (2), F.

Kastrau (2), W. Huber (2). (1) University Hospital Zurich, Switzerland. (2) University Hospital Aachen, Germany.

Aims: In the present study, we were interested in the neurofunctional representations of ambiguity processing by using functional magnetic resonance imaging (fMRI). **Methods:** 12 right-handed, healthy adults aged between 21 and 29 years (6 male, 6 female) underwent an ambiguity resolution task with 4 different conditions (dominant vs. non-dominant; dominant vs. distractor; non-dominant vs. distractor; distractor vs. distractor). **Results:** After subtraction of the corresponding control task (distractor vs. distractor) we found significant activation especially in the thalamus and some parts of the basal ganglia (caudate nucleus, putamen). **Conclusions:** Our findings implicate a participation of the thalamus and other basal ganglia circuits in high level linguistic functions and match with theoretical considerations on this highly controversial topic. Subcortical neural circuits probably become activated when the language processing system cannot rely entirely on automatic mechanisms but has to recruit controlled processes as well. Furthermore, we found broad activation in the inferior parietal lobule, the prefrontal gyrus, pre-SMA and SMA and the cingulate cortex. This might reflect a strategic semantic search mechanism which probably can be illustrated with connectionist models of language processing. According to this, we hypothesize a neuroregulatory role for the thalamus and basal ganglia in regulating and monitoring the release of preformulated language segments for motor programming and semantic verification. According to our findings there is strong evidence, that especially the thalamus, the caudate nucleus, the cingulate cortex, the inferior parietal lobule and the prefrontal cortex are responsible for an accurate ambiguity resolution in the human brain. In addition to our data collected from healthy subjects, first results concerning patients with Parkinson's disease and Schizophrenia will be presented.

84. Neural correlates of computational and storage costs in sentence comprehension. R. Woodbury (1, 2) and D. Caplan (2). (1) Harvard-MIT Division of Health Sciences and Technology, Harvard University and Massachusetts Institute of Technology, Cambridge, US. (2) Neuropsychology Laboratory, Massachusetts General Hospital, Boston, US.

INTRODUCTION Processing syntactic structure involves both memory and computational operations. In the present study, we examined the neural basis of memory and computational costs in parsing and sentence interpretation using fMRI. We explored memory costs by adapting stimuli from Chen (2004) that have shown behavioral effects of Gibson's (1998, 2000) "storage" costs, which vary the number of thematic roles predicted by a verb without introducing additional differences in the type of predicted element or the word order of the sentence. We explored computational costs by varying the number of thematic roles that have to be assigned when a verb is encountered. This study differs from previous studies in that it focuses on two aspects of verb arguments: the expectations set up by the number of arguments of a verb, and the costs incurred because of the need to satisfy each of the arguments of a verb. **STIMULUS MATERIALS** Storage Costs Obligatory Transitive: Mary published a book which had impressed some critics and a young child Optional Ditransitive: Mary read a book which had impressed some critics to a young child. Obligatory Ditransitive: Mary gave a book, which had impressed some critics to a young child. In the storage cost sentences, the obligatorily transitive and optionally ditransitive sentences require the prediction of one noun phrase to complete the sentence grammatically, while the obligatorily ditransitive sentences require the prediction of two noun phrases. **Computational Costs** Transitive: The conductor realized that the train was ready to board. Intransitive: The conductor realized that the train was ready to leave. In the computational cost sentences, the transitive sentences require two thematic roles to be integrated at the verb, while the intransitive sentences only require one thematic role to be integrated. **EXPERIMENTAL METHODS.** 12 right-handed native speakers of English read plausible and implausible sentences in a rapid-presentation event-related (RPER) fMRI paradigm and made plausibility judgments of these sentences. Only responses to plausible sentences were considered when constructing the contrasts and statistical activation maps for the fMRI experiment to eliminate potential responses arising from the detection of implausible or impossible scenarios. Structural and BOLD-sensitive functional MRI images were obtained with a 3T Siemens Trio scanner (Siemens Medical Solutions USA Inc., Malvern, PA, USA). All preprocessing and statistical analysis of the fMRI data was performed using the SPM15 software package. **RESULTS AND CONCLUSIONS.** Neural correlates of computational and storage costs are individually demonstrable and spatially distinct. Neural correlates of the two separate storage cost contrasts overlap in four common regions, indicating that similar processes are taking place in these two related contrasts. Results are consistent with behavioral results using similar stimuli, which indicate that transitive sentences have higher processing costs than intransitive sentences, and obligatorily ditransitive sentences have higher processing costs than optionally ditransitive and obligatorily transitive sentences, with no cost difference between optionally ditransitive and obligatorily transitive sentences. **REFERENCES.** Chen, E. (2004). Characteristics of syntactic processing: An examination utilizing behavioral and fMRI techniques. M.I.T. Ph.D. Thesis, Speech and Hearing Sciences. Gibson E. (1998). Linguistic complexity: Locality of syntactic dependencies. *Cognition* 68: 1-76.

85. Template Construction Grammar and the Description of Visual Scenes. M.A. Arbib (1) J.-Y. Lee (1). University of Southern California, Los Angeles, US.

Elsewhere (e.g., Arbib 2006), we have suggested how the mirror system's linkage of action and perception may form part of a larger system integrating dorsal and ventral pathways to link words-as-articulatory-actions with a rich semantics based on assemblages of perceptual and motor schemes. The present study extends this work by eye-movement studies inspired by our earlier computational modeling (Arbib & Lee 2008) of the production of descriptions of visual scenes, using a spatially anchored layout of schema instances to provide the formal semantics for the description. More specifically, we have developed Template Construction Grammar (TCG) as a new version of Construction Grammar which works through competition and cooperation of constructions to derive a verbal description from a semantic representation, SemRep, in the form of a graph-

like hierarchical structure that bridges between vision and language. We report on an ongoing study that links eye movements to the temporal unfolding of the description of visual scenes that demonstrates the presence of a critical threshold for readout of assembled constructions which distinguishes speakers whose descriptions tend to be fragmentary from those whose descriptions more closely resemble complete sentences. We contrast results for on-line description during the scene display and post-scene description to show how SemRep is built from the perceived visual information and how it influences the choice of constructions for the produced utterance. Finally, we offer hypotheses for new brain imaging experiments based on posited localizations for the different mechanisms revealed by the eye-movement studies and our previous modeling. Arbib, M. A. (2006) Aphasia, apraxia and the evolution of the language-ready brain. *Aphasiology* 20: 1-30. Arbib, M. A. & Lee, J. (2008) Describing visual scenes: Towards a neurolinguistics based on construction grammar. *Brain Research* 1225: 146-162.

86. Concreteness effects at high repetition rate on N400-like potentials and reaction times. L. Renoult (1,2), M. B. Brodeur (1), J. B. Debruille (1,2,3). (1) Douglas Mental Health University Institute, Montréal, Québec, Canada (2) Department of Neurology and Neurosurgery, McGill University, Montréal, Québec, Canada (3) Department of Psychiatry, McGill University, Montréal, Québec, Canada.

The N400 is a negative deflection which develops between 250 and 500 ms after the onset of a stimulus and has consistently been associated with semantic processing. Recently, Debruille and Renoult (2009) have shown that N400 effects of semantic matching and semantic category could be obtained with highly repeated words. They proposed that the persistence of these effects after numerous repetitions could allow to study very specific categories of words, notably categories that include only a few exemplars. However, it is unknown if these results obtained with prime-target word pairs could be generalized to single words paradigms and to less robust effects like concreteness effects. N400 amplitude is generally greater and reaction times faster for concrete than for abstract words. These concreteness effects are more consistently observed in tasks where meaning has to be explicitly processed. On the other hand, these effects are reduced when words are repeated. The topography and laterality found for ERP effects of concreteness tend to be heterogeneous, similar to the important variations in their localization reported by fMRI studies. Our knowledge of the processing differences associated with abstract and concrete words could thus benefit from the possibility of studying smaller and more homogeneous categories of words. To verify that this could be feasible, the present study aimed to test if concreteness effects on N400 and reaction times would still be observed despite high rates of repetition in a task where semantic processing would be explicitly required. Six concrete and six abstract words, matched in frequency of usage, were presented each twenty times on a computer screen while 15 participants categorized them as belonging to one or the other category. The EEG was recorded from 30 active points all referenced to the right ear lobe. Significant effects of concreteness were obtained both for reaction times and ERPs. The amplitude of a N400-like deflection was found to be greater for concrete than for abstract words. An independent component analysis (ICA) revealed that the independent components accounting for the effect of concreteness in the N400-like time window were very similar to that found for the effect of semantic congruity in repeated and non-repeated conditions. These findings constitute additional evidence for the analogy between the N400 observed in non-repeated conditions and the N400-like ERP observed with high rates of repetition (Debruille & Renoult, 2009). Moreover, they extend our previous results by showing that these effects can be obtained not only with prime-target word pairs but also with single words. The possibility of repeating single words and thus of using small and more homogenous samples of words could allow the study of more precise conceptual categories. Dissociations inside the concrete and abstract categories have been observed but have been mainly limited to the contrast between animals and artifacts and have left abstract concepts relatively unexplored. It is likely that investigating typical exemplars of sub-categories of abstract and concrete concepts could explain some of the variations of the localization of concreteness effects in the brain.

87. Left Ventrolateral Prefrontal Cortex Contributions to a Language-based, Object Use Generation Task. E. G. Chrysikou (1), and S. L. Thompson-Schill (1). (1) University of Pennsylvania, Philadelphia, US.

Introduction: Work in neuroscience has revealed the critical role of the frontal lobes in higher-order cognitive tasks, during which one has to exercise cognitive control, such as working memory tasks (e.g., backward digit span, n-back task), rule switching (e.g., the Wisconsin Card Sorting Task), or resolving interference from unwanted information (e.g., the Stroop task). Specifically, studies of conceptual processing often require participants to engage in a close-ended, deliberate memory search (e.g., retrieving a verb associated with an object) and implicate the prefrontal cortex (PFC), especially the left ventrolateral prefrontal regions. Yet, much of human thought requires more open-ended, spontaneous memory retrieval. Recent evidence from neuroscience and neuropsychological patients with PFC lesions would suggest that open-ended tasks—which populate much of everyday human cognition—may benefit from a tradeoff between regions involved in rule-based processing (i.e., PFC) and regions involved in processing of object attributes (i.e., visual cortex). Hypothesis: This study examined whether the PFC is similarly implicated in close-ended and open-ended linguistic tasks. We hypothesized that closed-ended tasks (i.e., having either one or a finite number of possible responses for which the search in conceptual space is deliberate) depend on the controlled retrieval of conceptual memory through the selection of one prepotent response facilitated by the left ventrolateral PFC. Conversely, open-ended, divergent tasks (i.e., having an infinite number of possible responses, for which the search in conceptual space is non-deliberate) rely on the activation of posterior temporal-occipital regions specializing in object attributes within a distributed semantic network. Design & Methods: In the present experiment we combined a close-ended

task (i.e., common use generation, e.g., baseball bat to hit a baseball) and an open-ended task (i.e., uncommon use generation, e.g., baseball bat to use as a rolling pin) in an event-related, fMRI paradigm to examine whether they would lead to different types of semantic retrieval strategies. Seventy-two black-and-white photographs of everyday objects were used as experimental stimuli and 72 abstract black-and-white images were used as baseline stimuli. Sixteen (N = 16) right-handed, native English speakers (mean age = 23.08, 5 males) participated in the study. During the experimental blocks, participants performed either the Common-Use or the Uncommon-Use generation task. Results & Discussion: Whole-brain analyses revealed two regions of interest (ROIs): (1) the left inferior frontal gyrus (Brodmann's Areas 44, 45, 47) and (2) the left lateral occipital complex. Qualitative behavioral and neuroimaging (ROI) analyses suggest that the PFC is involved in determining the well-established aspects of object use; however, its involvement is moderated under circumstances of impromptu goal achievement. These results are consistent with distributed accounts of semantic memory according to which semantic knowledge is organized in a flexible distributed conceptual network that can be selectively activated to focus on different aspects of our knowledge based on task demands. They further support a view of the PFC as a dynamic filtering mechanism that selectively maintains task-relevant information while gating task-irrelevant information.

88. Executive dysfunction is related to reading disability in adolescents born at term and prematurely. R.E. Frye (1), K. Smith (2), P. Swank (1) and S. Landry (1). (1) University of Texas Health Science Center, Houston, US (2) University of Texas Medical Branch, Galveston, US.

Despite the fact that children born at very low birth weight (VLBW) without obvious brain damage are at high risk for cognitive dysfunction the neurological basis of such dysfunction for children born VLBW has not been well studied. Identifying the neurological basis of such cognitive dysfunction for children born VLBW may provide insight into educational, neuropsychological and medical treatment for these individuals and eventually lead to the development of an early marker for impending cognitive dysfunction. Since few studies have linked cognitive limitations and academic achievement in children born VLBW, we studied neuropsychological, language, executive function performance in relation to reading achievement in our longitudinal cohort of term and medically low and high-risk children born VLBW. Although premature children were not found to be at high risk for reading disability as compared to the term children, children born VLBW at high medical risk who were poor readers were found to manifest lower executive function skills as compared to other poor readers, suggesting that poor reading in children born VLBW at high risk is associated with executive dysfunction. However, reanalysis of this data demonstrated executive function performance was found to be related to all reading groups with this relation much stronger for the children born VLBW at high risk as compare to the other birth groups. We obtained diffusion tensor imaging (DTI) and magnetoencephalography (MEG) studies on a carefully selected group from our longitudinal cohort. Our DTI and MEG data suggests that poor reading children born VLBW demonstrate abnormalities in the same neural systems as poor reading children born term but children born VLBW demonstrated additional, potentially more severe, abnormalities in these same neural systems. Most interestingly, DTI changes were particularly evidence in the left superior longitudinal fasciculus (SLF), the major connection between the left posterior brain and the left frontal lobe, and neurophysiological changes in the left frontal lobe, possibly as a consequence of abnormalities in the left SLF. Atypical frontal activation is also seen in both children and adults with reading disability. Our research on young adults with a history of dyslexia suggests that rather than measuring absolute frontal activation, it is important to measure causal connectivity. Our studies using Granger causality suggest that young adults born at term with a history of dyslexia, particularly those that remain as poor readers into adulthood, may suffer from a lack of top-down activation of posterior language regions, suggesting a failure of left frontal executive systems as a key component of their reading disability. We believe that frontal lobe pathology is shared between reading disability in children born both at term and VLBW and discuss how failure of the executive is an important component in the development of cognitive weaknesses in both groups with the pathology being more severe in children born VLBW, resulting in more extensive neuropsychological weaknesses.

89. Is relational reasoning dependent on language? A voxel-based lesion analysis in patients with aphasia. J. Baldo (1), S. Bunge (2), S. Wilson (3), and N. Dronkers (1,4,5). (1) VA Northern California Health Care System, Martinez, CA, US (2) University of California, Berkeley, CA, US (3) University of California, San Francisco, CA, US (4) University of California, Davis, CA, US (5) University of California, San Diego, CA, US.

The ability to reason and problem-solve is a critical component of human behavior. Previous studies have suggested that language may underlie this ability, even when tasks are non-verbal. In the current study, we tested this hypothesis by analyzing behavioral and neuroimaging data from a large group of left-hemisphere stroke patients (n = 107) suffering from a range of aphasia severity from none to severe. Patients were tested on the Raven's Colored Progressive Matrices (RCPM), a non-verbal test of reasoning that requires participants to complete a visual pattern or sequence with one of six possible choices. For some items, the solution could be determined by visual pattern-matching, but other items required relational reasoning, that is, the ability to identify and integrate two or more dimensions of relational change. As predicted, performance on the relational-reasoning items was disproportionately impaired in patients with aphasia, relative to non-aphasic, left-hemisphere patients. A voxel-based lesion symptom mapping (VLSM) procedure was used to relate patients' RCPM performance with areas of damage in the brain. Results showed that impaired relational reasoning problems was associated with lesions in the left middle and superior temporal gyri, regions essential for language processing, as well as in the left inferior parietal lobule (shown in red). In contrast, the visual pattern-matching condition was associated with more posterior regions in visual association cortex

(shown in blue). These findings provide compelling support for the idea that language is critical for higher-level reasoning and problem-solving.

90. Preparing People with Aphasia for Distractions of Daily Life. A. Hancock (1), M. Bamdad (1). (1) *The George Washington University, Washington, D.C., US.*

Background Resource Allocation model (Kahneman, 1973, Norman & Bobrow, 1975), often applied in attention and other cognitive domains, has two primary components: a (finite) cognitive resource and an allocator, or manager, of that resource. Later versions propose more than a single resource (Navon & Gopher, 1979). Dual-task paradigms are often used to examine the Resource Allocation model but it is difficult to parse the contributions of the allocator (cognitive processing) from the resource (cognitive capacity). The current study utilizes a within-subject design manipulating levels of distraction to isolate the processes of the allocator while holding the resource demand constant. Studies have confirmed the prevalence of cognitive-linguistic deficits in patients with aphasia and to some degree have examined the deleterious effect of distraction (LaPointe, et al. 2005; Murray, Holland & Beeson, 1997, 1998; Stierwalt & Murray, 2002). Conditions more similar to everyday environments, with simultaneous visual and auditory distraction, need to be explored. It is possible that practicing with a CD of distracting noise (a common practice) is a valuable step toward performance in life outside the therapy room. If language performance deteriorates as distraction is added (auditory alone and then auditory with visual), a strain on the allocator's ability to ignore distraction's pull for attention will be revealed. This would have implications for training the allocator rather than (or at least in addition to) general cognition. This study compares cognitive-linguistic performance in three environments: a quiet treatment room, a treatment room with a CD of cafeteria sounds playing, and a real cafeteria. **Method.** Four participants with Aphasia (58-61 years old, Western Aphasia Battery AQ scores 55-83) completed a battery of cognitive-linguistic tasks in each environment. Environments were assigned in a counterbalanced order across participants. Language samples (e.g., picture description and personal narrative) were analyzed for number of words, morphemes, correct information units (CIUs), and content units, which were used in calculating indices of Lexical Efficiency and Grammatical Support from the Communication Effectiveness Profile (Helm-Estabrooks & Albert, 1991, Nicholas & Brookshire, 1993) **Results.** Results from these four heterogeneous participants are reported separately in effort to investigate potential differences across the diverse population of patients with aphasia and direct future research. No distinct pattern could be noted across the four participants, within a participant across the three conditions, or between the two types of language samples (i.e., picture description and personal narrative). Even when performance was different across conditions, it was not always best in quiet condition and the CD condition did not necessarily fall between quiet and real cafeteria conditions. **Conclusions.** Effect of distraction is not obviously detrimental to language, as is usually assumed when patients complain of increased difficulty in distraction. Individual differences likely exist but, at this preliminary stage, do not appear to be associated with aphasia severity. Further research, perhaps using more sensitive measures, is needed. **Significance.** Results of this study caution clinicians and researchers to be wary of manipulating distraction in attempt to provide a hierarchy of difficulty for cognition or cognitive processing.

Aging, plasticity and brain injury

91. Effects of semantic and syntactic context on open-class words—comparing the old and the young. C. Lee (1), K.D. Federmeier (1). (1) *University of Illinois, Champaign, US.*

Event-related brain potentials (ERPs) were used to investigate how aging affects the buildup and use of semantic and syntactic context information. Three types of contexts were used: (1) congruent sentences, with both valid syntactic structure and coherent semantic information, (2) syntactic prose, with valid syntactic structure but no coherent semantic content, and (3) scrambled sentences, without either valid syntactic or coherent semantic information. College-aged and older adult (above age 65) participants were asked to read the sentences word by word and perform a word recognition task at the end of each sentence and a sentence recognition task at the end of every two blocks. ERPs were averaged for each word according to its ordinal position in the sentence. The data from young participants replicated previous findings (Van Patten & Kutas, 1991), showing increasing N400 reduction over the course of congruent sentences. Older adults showed an initial N400 reduction, but then little change over word position, suggesting difficulty rapidly integrating word information to appreciate message-level meaning (c.f., Federmeier & Kutas, 2005). However, behavioral results from the two age groups showed very similar patterns. Both younger and older adults recognized words most easily if the word was originally presented with joint semantic/syntactic context, less well with syntactic context alone and least well with the scrambled sentence context. Data from the sentence recognition task showed a similar pattern, but with greater overall age differences. Taken together, the results suggest that in older as in younger adults, basic word processing benefits from context information. However, especially as revealed by temporally sensitive measures, the appreciation of message-level information seems to become less efficacious with advancing age, and this seems to be at least in part due to difficulty rapidly building and updating message-level meaning structures from the on-going word stream.

92. Aging effects in a homonym processing paradigm; an fMRI-study. S. Ketteler (2), R. Vohn (2), F. Kastrau (2), W. Kawohl (1), L. Jäger (3), A. Theodoridou (1), W. Huber (2), D. Ketteler (1). (1) *University Hospital Zurich, Switzerland.* (2) *University Hospital Aachen, Germany.* (3) *Department of Linguistic, University Aachen, Germany.*

Aims: Our aim was to clarify putative aging effects in a homonym processing paradigm. According to previous studies

conducted by our group we found that especially the left thalamus, caudate nucleus, the cingulate cortex, the left inferior parietal lobule and the left prefrontal cortex were responsible for an accurate ambiguity resolution in the human brain. The question was whether these effects could be replicated in older individuals. **Methods:** 12 healthy right handed individuals (55-65 years; 58.2 years mean age; dementia excluded by CERAD) underwent an ambiguity resolution task with 4 different conditions (dominant vs. non-dominant; dominant vs. distractor; non-dominant vs. distractor; distractor vs. distractor). Older adults were compared to a group of 12 younger adults (21-29 years). **Results:** After subtraction of the corresponding control task (distractor vs. distractor) we found significant activation especially in the thalamus and some parts of the basal ganglia (right caudate nucleus, left putamen), the cingulate gyrus, prefrontal language areas and especially in inferior parietal cortex areas. Compared to younger adults, the right as well as the left inferior parietal cortex showed broad activity. **Conclusions:** Subcortical language processing could be replicated in our study. Comparing functional data of young and old adults, there was hemispheric asymmetry reduction concerning cortical as well as subcortical areas in old adults. Regarding inferior parietal cortex areas, responsible for ambiguity resolution, these areas were broadly activated in both hemispheres. This also applies for left and right putamen and thalamic areas. On the one hand, there might be a compensatory effect in older adults mentioned by Cabeza et al. (1997), on the other hand, dedifferentiation (Lindenberger, 1997) might be a phenomenon of aging in general and not just a compensatory phenomenon. Interestingly, delateralisation does not only affect cortical areas but also includes subcortical structures. Furthermore, delateralisation might be a good explanation for the potential of recovery and neuroplasticity in cases of aphasia or brain lesion. Ongoing studies concerning patients with Parkinson's disease, Tourette syndrome and Schizophrenia will put spotlight on this interesting mechanisms of ambiguity processing and subcortical/ cortical brain areas.

93. fMRI shows age-related changes in resolving a temporary structural ambiguity. *D. Gunawardena (1), C. McMillan (2), J. Peelle (3), V. Troiani (4), and M. Grossman (5).* (1) University of Pennsylvania, Philadelphia, US. (2) University of Pennsylvania, Philadelphia, US. (3) MRC Cognition and Brain Sciences Unit, Cambridge, UK. (4) University of Pennsylvania, Philadelphia, US. (5) University of Pennsylvania, Philadelphia, US.

Age-related brain activation changes are typically characterized by shifts from unilateral to bilateral activations involving contralateral homologues. However, previous neuroimaging work investigating grammatical processing demands in sentence comprehension has not conformed to this pattern. Instead, brain regions associated with sentence processing (e.g. inferior frontal cortex; IFC) were upregulated by healthy seniors relative to young adults. A limitation of the previous finding is that sentence materials required explicit decision-making, and thus task-related resource demands may have been confounded with grammatical processing demands during aging. The present fMRI study investigates age-related changes in sentence processing while passively reading a sentence with a temporary structural ambiguity. In this study, young adults (n=10) and healthy seniors (n=13) passively read 80 sentences in a phrase-by-phrase presentation. All of the sentences contained verbs preferring a direct object structure (e.g. "heard"). In half of the stimuli the verb was embedded in sentences with a "more compatible" sentence structure (e.g. a direct object structure, such as "The mayor heard the election result on the radio"). In half of the stimuli the same verbs were embedded in sentences with a "less compatible" grammatical frame (e.g. a sentence complement structure, such as "The mayor heard the election result was fixed"). All contrasts focus on the region where the temporary structural ambiguity is resolved minus a baseline, grammatically-neutral noun phrase encountered earlier in the sentence. Both young adults and healthy seniors activated IFC and dorsolateral prefrontal cortex (dlPFC) ($p < .001$ cluster-corrected) more prominently on the left than the right in the less compatible stimuli. A between-groups comparison revealed significantly greater right dlPFC activation in young adults relative to seniors ($p < .001$, uncorrected). Based on our prior work, we hypothesize that dlPFC activation is related to executive resources supporting strategic decision-making during the interpretation of a sentence with a temporary structural ambiguity. Marginally greater left IFC activation is seen in seniors relative to young adults ($p < .003$, uncorrected). We hypothesize that healthy seniors have executive resource limitations, and instead attempt to upregulate components of a core sentence processing network. These findings suggest that age-related changes in activation during sentence processing do not necessarily involve contralateral recruitment, but appear to entail up-regulation of specific brain regions needed to process stimulus material.

94. Patterns of cortical thinning in three subtypes of primary progressive aphasia. *Rogalski, E. (1), Cobia, D. (2), Wieneke, C. (1), Weintraub, S. (1), Mesulam, M-M. (1).* (1) Cognitive Neurology and Alzheimer's Disease Center, Northwestern University, Chicago, IL, US (2) Department of Psychiatry and Behavioral Science, Northwestern University, Chicago, IL, US.

Primary Progressive Aphasia (PPA) is a neurodegenerative syndrome characterized by a gradual dissolution of language, but relative sparing of other cognitive domains during the initial stages of the disease. Clinically most PPA patients can be classified into one of three subtypes, agrammatic (PPA-G), logopenic (PPA-L) and semantic (PPA-S), based on their language deficit profile. Structural and functional imaging show that the clinical focality of PPA is matched by the anatomical selectivity of damage to the left hemisphere perisylvian language network. Previous Voxel Based Morphometry studies suggest distinct anatomical distributions of atrophy by subtype. Recent advances in surface-based computational anatomy offer access to richer information about neuroanatomical changes, including detailed quantification of cortical thickness, surface area, and volume. The present study utilized these advances to examine cortical thickness in the three subtypes of PPA using the computational image analysis toolkit Freesurfer. MRI scans from 4 PPA-G, 7 PPA-L, and 5 PPA-S patients and 17 controls

were processed using FreeSurfer's surface-based method of estimating cortical thickness, which is capable of detecting submillimeter differences between groups. Group differences were determined by conducting a general linear model analysis across all matching vertices along the surface of the cortex. Results showed asymmetrical cortical thinning in the left hemisphere for all patients. Distinct cortical thinning patterns were also evident among the groups. Atrophy in the PPA-S subtype was the most severe, specifically targeting the anterior components of the language network including the temporal pole. The PPA-G subtype demonstrated the widest regional distribution of atrophy, encompassing both Wernicke's and Broca's areas. The PPA-L group showed the least cortical thinning, predominantly located in the posterior language network, specifically including Wernicke's area and Brodmann area 37. The observed patterns of atrophy are consistent with findings from other structural imaging analysis methods and support distinct anatomical substrates for the three clinical subtypes of PPA.

95. Cost Function Masking during Normalization of Brains with Focal Lesions: Still a Necessity? S. Andersen (1), S. Rapcsak (1,2), and P. Beeson (1). (1) University of Arizona, Tucson, AZ (2) Southern Arizona VA Health Care System, Tucson, AZ.

Objective: Normalization of brain images allows for comparison and aggregation of data across individuals. In cases of focal damage, the loss of brain tissue and deformation of cortical borders and ventricular shape presents a challenge for the normalization process. To address this issue, Brett and colleagues (2001) recommended the use of cost function masking wherein the damaged portion of the brain is ignored (i.e., masked) during computation of normalization parameters. More recently, Crinion and colleagues (2007) questioned the necessity of masking when normalization is implemented using unified segmentation. Using 10 brains with simulated lesions, they found that normalization with cost function masking did not significantly reduce error compared to normalization implemented without a lesion mask. These findings were not entirely consistent with our experience because visual inspection of patient brains normalized with and without masking in our lab suggested that differences were sometimes marked (see Figure 1). The purpose of this study was to examine the outcomes from normalization with and without masking in scans from actual patients with focal damage. Method: High resolution MRI brain scans were acquired from 43 individuals with left hemisphere damage as a result of left middle cerebral artery (n=32) and posterior cerebral artery (n=11) strokes. Binary lesion images were created by outlining damaged areas in native space using MRICron software (Rorden & Brett, 2000). Brains were then normalized with and without lesion masks using unified segmentation in SPM5, consistent with Crinion et al. (2007). In both cases, spatial normalization parameters generated during unified segmentation were applied to the patient brain and the lesion image. Lesion volumes from masked and unmasked normalization were calculated and compared using a two-tailed t-test. Results: The mean lesion volume calculated without masking was significantly smaller than that derived when masking was used (122,493 mm³ vs. 126,616 mm³; t=3.11, p=.003). This pattern of unmasked < masked lesion volume was observed in 36 of the 43 scans analyzed. In order to explore whether this difference varied as a function of lesion size, we first calculated the percent difference as follows: $[1 - (\text{unmasked volume}/\text{masked volume})] * 100$. We then examined the correlation between percent difference (unmasked/masked) and the masked lesion volume. The relationship was not significant (r=.19, p=.222). Conclusion: Our results show that failure to employ cost function masking during normalization typically leads to underestimation of lesion size. In addition, this underestimation is not systematically related to lesion size, making reconciliation between the unmasked and masked volumes difficult. Therefore, we advocate the continued use of cost function masking for normalization of brains with focal lesions. References Brett, M., Leff, A. P., Rorden, C., & Ashburner, J. (2001). Spatial normalization of brain images with focal lesions using cost function masking. *NeuroImage*, 14(2), 486-500. Crinion, J., Ashburner, J., Leff, A., Brett, M., Price, C., & Friston, K. (2007). Spatial normalization of lesioned brains: Performance evaluation and impact on fMRI analyses. *NeuroImage*, 37(3), 866-875.

96. Agrammatism revisited: Reorganization of cortical activity associated with a glioma in syntax-related regions. R. Kinno (1),(2), Y. Muragaki (3), T. Hor i(3), T. Maruyama (3), M. Kawamura (2), and K. L. Sakai (1) (1) Department of Basic Science, Graduate School of Arts and Sciences, The University of Tokyo, Tokyo, Japan. (2) Department of Neurology, Showa University School of Medicine, Tokyo, Japan. (3) Department of Neurosurgery, Tokyo Women's Medical University, Tokyo, Japan.

In a functional magnetic resonance imaging (fMRI) study, we have devised a picture-sentence matching task and reported that pars triangularis (L. F3t) of the left inferior frontal gyrus (extending to pars opercularis (L. F3op)) and the left lateral premotor cortex (L. LPMC) are selectively involved in syntactic comprehension (Kinno et al., 2008). Using the same task, we have recently examined 21 patients with a glioma in the left frontal cortex (Kinno et al., in press). This task included three main conditions of sentence types: canonical / subject-initial active sentences (AS: "o pushes □"), noncanonical / subject-initial passive sentences (PS: "□ is affected by o's pushing it"), and noncanonical / object-initial scrambled sentences (SS: "As for □, o pushes it") (see Figure). We found that the L. F3op/F3t-damaged patients had more profound deficits in the comprehension of noncanonical sentences, whereas the L. LPMC-damaged patients had more profound deficits in the comprehension of object-initial scrambled sentences. These results established that a lesion in L. F3op/F3t or L. LPMC is sufficient to cause agrammatic comprehension. The present study was intended to clarify the neural mechanisms of any cortical reorganization induced by a lesion in these two regions. Using fMRI, we examined 18 patients with a glioma in (1) L. F3op/F3t, (2) L. LPMC, or (3) other left frontal regions. In addition to AS, PS, and SS, we tested one sentence control condition (SC) with subject-initial active

sentences, in which intransitive verbs were used (“○ and □ run”). The participants judged whether or not the sentence matched the action scene depicted by the picture by pushing one of two buttons. We performed group analyses using SPM5, and cortical activity was estimated by the comparison of (AS + PS + SS) – SC ($P < 0.05$, corrected for multiple comparisons). Similar to normal controls, the third group with a glioma in left frontal regions other than L. F3op/F3t and L. LPMC showed left-lateralized activation in F3op/F3t and LPMC. In contrast, the L. F3op/F3t-damaged patients showed greatly reduced activation in the bilateral F3op/F3t and LPMC, whereas the L. LPMC-damaged patients showed enhanced activation in the bilateral F3op/F3t and LPMC. These results demonstrated differential reorganization of frontal activity depending on the location of a glioma, suggesting the independent cortical network for each of the syntax-related regions. References. Kinno, R., Kawamura, M., Shioda, S., & Sakai, K. L. (2008). Neural correlates of noncanonical syntactic processing revealed by a picture-sentence matching task. *Human Brain Mapping* 29, 1015-1027. Kinno, R., Muragaki, Y., Hori, T., Maruyama, T., Kawamura, M. & Sakai, K. L. (in press). Agrammatic comprehension caused by a glioma in the left frontal cortex. *Brain and Language*.

97. Neural Mechanisms Underlying Treatment-Related Improvement in Logopenic Primary Progressive Aphasia: an fMRI case study. B. Bonakdarpour (1,2), H.Cho (2), M.L. Henry (2), R. King (2), S.Z Rapcsak (1,2,3) P.M. Beeson (2,1). (1) Department of Neurology, University of Arizona Health Sciences Center, Tucson, US (2) Department of Speech and Hearing Sciences, University of Arizona, Tucson, US, (3) Neurology Section, Southern Arizona VA Health Care System.

Background: Picture naming in normal individuals recruits a widespread network of brain regions, including inferior temporo-occipital cortex/fusiform gyrus (FG), superior and middle temporal gyri (STG/MTG), and inferior frontal gyrus/Broca's area (IFG) (Price et al., 2005). Atrophy affecting these cortical regions may result in a naming deficit in patients with primary progressive aphasia (PPA). Although PPA is a progressively worsening condition, treatment studies have shown the potential for language improvement in some of these patients (e.g., see Henry et al., 2008). The neural mechanism of recovery, however, has yet to be elucidated. The purpose of this study was to investigate functional changes in brain networks involved in picture naming following successful treatment for lexical retrieval in an individual with PPA. Methods: The participant in this study was a 77 year-old male with logopenic PPA who reported onset of symptoms 15 months prior to start of treatment. VBM analysis showed cortical atrophy that was particularly marked in the left temporoparietal regions (see Figure). The patient showed significant improvement in naming performance after two weeks of intense lexical/semantic stimulation treatment, and improvements were maintained at two months post-treatment. Functional MRI scans were obtained immediately before and after treatment using a picture naming task presented in a long trial event-related design. Images were analyzed using SPM5 to examine whole brain activation as well as activations in the following left-hemisphere regions of interest (ROI): fusiform gyrus (FG) superior/middle temporal gyri (STG/MTG), inferior frontal gyrus (IFG), and parietal lobe (superior/inferior parietal lobule: SPL/IPL). Results: Whole brain analysis of the pre-treatment fMRI scan showed bilateral activations in FG, STG/ MTG, and SPL/IPL (see Figure 1). The scan obtained immediately following treatment showed activation of the same network, but there was a marked reduction in the extent of activation in all cortical areas. ROI analysis confirmed the findings of the whole-brain analysis (see Table). A second follow-up fMRI scan was obtained two months post-treatment, but the results were not usable due to excessive motion artifact. Discussion: Pre-treatment scans in this patient indicated activations in some of the left-hemisphere cortical regions that are also recruited by normal individuals during picture naming tasks (FG, STG/MTG) (Price et al., 2005). However, there were also significant activations in brain areas that are not part of the normal object naming network (e.g., bilateral SPL/IPL, right STG/MTG). Post-treatment improvement in naming performance was accompanied by reduced levels of activation within the same cortical network that was recruited during the pre-treatment scan, rather than a spatial redistribution of activations or recruitment of new cortical areas. These findings are consistent with other functional imaging studies showing a reduction in cortical activation during behavioral training/skill learning. Additional imaging studies of pre- and post-treatment language performance are needed to determine whether our findings generalize to other patients with PPA or stroke-induced aphasia.

98. Proportional Recovery from Mild-Moderate Aphasia after First-Time Stroke. R.M. Lazar (1) B.M. Minzer (1) D. Antoniello (1) J. Festa (1) J.W. Krakauer (1) R.S. Marshall (1). (1) Columbia University College of Physicians & Surgeons, New York, US.

Objective: To determine whether recovery from aphasia after first-time stroke in the initial 90 days follows a comparable proportional model as that seen in motor recovery. Background: Although most improvement from post-stroke aphasia occurs within the first three months, there remains unexplained variability in recovery. We have previously shown that factors such as infarct size, initial syndrome severity and age only account for about 30% of the variance. We recently reported that there was a robust (70%) proportional relationship between initial syndrome and upper-extremity motor recovery as measured by change scores. Design/Methods: Twenty-three stroke patients with mild-moderate aphasia from image-verified, first-time stroke had a composite score (comprehension, repetition and naming on the Western Aphasia Battery) obtained on stroke admission within 72 hours after onset and at 90 days. All were right handed with left hemisphere ischemic infarction. None were globally aphasic. The initial severity scores and change scores from baseline to 90 days were used to assess whether there was proportional recovery in this cohort. Results: A regression analysis showed a clear relationship between initial aphasia severity and the change score at 90 days ($R^2 = 0.76$, $p < 0.001$). The slope of the curve indicated a 79% proportional recovery here, similar to the 70% found for motor recovery. There was a relationship between initial syndrome and the score at 90 days ($r = 0.42$, $p = 0.04$), which only accounted for 18% of the variance. Lesion volume and age did not

predict 90 scores. Adding initial syndrome severity, age and lesion volume to the proportional model only increased R2 by 5%. Conclusions: We showed that, like motor recovery, there was a tight proportional relationship of aphasia recovery to initial impairment. The comparability of 70% recovery of motor skills and 79% for language recovery suggests the hypothesis that there may be a common, independent recovery mechanism for the restitution of post-stroke function in the early recovery period.

99. Enhancing language skills in adults with Asperger's syndrome using repetitive transcranial magnetic stimulation over Broca's area. S.Fecteau (1), L.Oberman (1), and A.Pascual-Leone (1). (1) Berenson-Allen Center for Noninvasive Brain Stimulation, Beth Israel Deaconess Medical Center and Harvard Medical School, Boston, US.

The aim of this work is to investigate whether language skills can be improved in individuals with autistic spectrum disorders (ASD) using non-invasive brain stimulation with repetitive transcranial magnetic stimulation (rTMS). The rationale comes from three lines of experimental evidence: (1) individuals with ASD display abnormalities in Broca's area and its contralateral homologue; (2) functional and volumetric MRI studies found correlation between Broca's area and diagnostic scores in individuals with ASD, and; (3) modulation of parts of Broca's area can improve language skills in stroke patients with non-fluent aphasia. Taken together, these data suggest that a dysfunction within Broca's area underlies language impairments in ASD, such that modulating activity levels within this region might enhance language skills. The specific objective of this study was to assess the behavioral impact on naming abilities of modulating activity in left and right Broca's region in adults with Asperger's syndrome (AS) and matched neurotypical controls. We conducted a five-stimulation site, double-blind, multiple crossover, pseudo-randomized, sham-controlled trial in individuals with AS and healthy matched controls. Object naming was assessed before and after low-frequency real or sham rTMS of the left or the right pars opercularis, the left or the right pars triangularis, as guided stereotaxically by each individual's brain MRI. TMS was applied with parameters aimed at suppressing activity in the targeted brain region. In neurotypical controls TMS-induced disruption of right or left pars opercularis, or pars triangularis did not lead to significant changes in naming, supporting data reviewed from previous studies in healthy individuals. However, in ASD subjects naming skills were significantly improved following TMS-induced disruption of the left pars triangularis. Specificity of this beneficial effect was demonstrated by observation of the opposite behavioral impact after stimulation of an adjacent area: lengthened response latency on naming after stimulation of the left opercularis. No significant change was observed after stimulation of the pars opercularis or pars triangularis of the right hemisphere. There are three main findings from this work. First, low-frequency rTMS appears to be safe in adults with AS and can enhance language skills. Second, these results suggest a causal link between the behavior of naming and Broca's area in AS, whereas the effects of rTMS did not significantly modulate language skills in neurotypical individuals. This supports the notion that although language skills such as naming objects (a basic but milestone ability in language acquisition) appear intact in adults with AS, the related neural network appears to be different from neurotypical individuals. Third, these findings suggest that language behaviors can be improved in AS with non-invasive brain stimulation, encouraging further examination for developing neuromodulation-based approach to enhance speech abilities in this population.

100. Reversal of the concreteness effect for verbs in semantic dementia. M.F. Bonner (1), L. Vesely (2), C. McMillan (1), B. Avants (1), and M. Grossman (1). (1) University of Pennsylvania, Philadelphia, US (2) State University of New York at Buffalo, Buffalo, New York, US.

Semantic memory is the long-term representation of the meaning of words, objects, actions and the like. Most of the work assessing word meaning in semantic memory involves fMRI assessments of neurologically intact adults. Patients with semantic dementia (SD) represent an important source of converging data regarding the cognitive and neural basis for semantic memory. These patients have a striking impairment in semantic memory, but the basis for this deficit is unclear. Most observations of SD emphasize the role of an amodal semantic component in their semantic memory deficit. However, findings of a "reversal of the concreteness effect" in SD, which is a deficit for words with concrete referents relative to words with abstract referents, implicate degraded visual perceptual feature knowledge. This suggests that an amodal semantic component does not fully account for the semantic deficit in SD. In the present study, we reproduce the finding of a "reversal of the concreteness effect" for verbs in SD patients using a new task, and we extend previous observations by examining cortical atrophy in these patients, demonstrating a direct correlation of performance with cortical atrophy. We employed a two-alternative, forced-choice measure of lexical semantic associative knowledge. SD patients (n=11) were compared with patients with the clinical diagnosis of probable Alzheimer's disease (AD) (n=18). Patients with SD had significantly greater difficulty with concrete verbs ($z = -2.97$) than abstract verbs ($z = -1.75$), a "reversal of the concreteness effect" that was present in a majority of individual SD patients. MRI cortical thickness analyses showed that SD patients had significant atrophy in the anterior and inferolateral portions of the temporal lobes (Figure 1A). This is visual association cortex, and these areas may be important for storing and processing visual features for word meaning. Moreover, poor performance with concrete relative to abstract verbs correlated with atrophy of the right anterior temporal lobe in the subgroup of SD patients with imaging data (Figure 1B), suggesting that this region may contribute to the processing of visual semantic features. AD patients as a group did not show greater difficulty with concrete than abstract verbs, although some individuals had a "reversal of the concreteness effect." These observations raise the possibility that degraded visual feature knowledge contributes in part to the impaired comprehension of concrete words in SD. This is consistent with a sensory-motor account of semantic memory, in which concrete word knowledge relies on perceptual and motor feature representations in the sensory and motor association areas

of the brain.

101. Progressive neurodegenerative aphasia target distinct networks for language or multi-modal semantic knowledge. D. Sapolsky (1), A. Negreira (1), A. Bakkour (1), B. Dickerson (1). *Frontotemporal Dementia Unit, Massachusetts General Hospital, Boston, MA, US.*

Objective: Progressive neurodegenerative aphasia (primary progressive aphasia and related disorders) have been hypothesized to target distinct nodes of the dominant-hemispheric perisylvian language network. We sought to test this hypothesis using contemporary structural and functional neuroimaging techniques. Methods: Two types of MRI data were used: structural MRI scans from participants with progressive neurodegenerative aphasia and functional MRI scans from normal participants. Data were analyzed using methods to generate cortical thickness measures from structural data and network-connectivity measures from functional data. Seeds for functional connectivity analysis were derived from regions of focal cortical thinning generated from aphasia patient data, as well as coordinates of regions previously known to be activated in fMRI studies of language tasks. Topographical analyses were conducted of cortical thinning and functional connectivity maps to identify areas of overlap. Results: When analyzed as a single group compared to controls, the progressive aphasic patients demonstrate dominant hemisphere cortical thinning in perisylvian and temporopolar regions. Yet focused analyses demonstrate two distinct subgroups that fit with clinical diagnostic categories: progressive non-fluent aphasia (PNFA) and semantic dementia (SD). PNFA is associated with atrophy in inferior prefrontal and superior temporal regions with sparing of the temporal pole. SD is associated with atrophy of the temporal pole with relative sparing of superior temporal and prefrontal regions. Seeds generated from these separate atrophy maps identify, in normal young individuals, two separate functional networks in resting-state functional connectivity analyses that mirror the atrophy maps in PNFA and SD. Formal convergence analyses are ongoing to quantify the extent of overlap between these maps. Conclusions: Two distinct clinical forms of progressive neurodegenerative aphasia appear to target two separable large-scale brain networks that are important for normal human communication abilities: an inferior frontal-superior temporal network, regions of which are typically activated in fMRI language tasks, and a temporopolar network that is thought to be critical for multi-modal semantic knowledge.

102. Brain regions associated with age-related decline in naming. L. K. Obler (1, 2, 3), E. Rykhlevskaia (4), M. R. Clark-Cotton (1), D. Schnyer (5), J. Hyun (3, 2), D-S. Kim (1), A. Spiro, III (2, 6), M. Goral (7, 3), and M. L. Albert (1, 2). (1) Boston University School of Medicine, Boston, US. (2) Boston VA Healthcare System, Boston, US. (3) The Graduate Center of the City University of New York, New York, US (4) Stanford University, Stanford, US (5) University of Texas Austin, Austin, US. (6) Boston University School of Public Health, Boston, US. (7) Lehman College, City University of New York, Bronx, US.

Research Question: Brain regions deteriorate differentially with advancing age, and confrontation naming performance declines overall, becoming more variable across individuals with advancing age; we asked which cortical and subcortical regions and which connective tracts are associated with better maintenance of lexical retrieval in older adults. Methods: Structural Magnetic Resonance Imaging (MRI) and Diffusion Tensor Imaging (DTI) data were collected from 24 native speakers of English aged 55 to 80 ($x = 68$ years) whose education averaged nearly 4 years of college. All had corrected vision if necessary. All had been administered a computerized version of the Boston Naming Test (BNT) and the Action Naming Test (ANT) within the half year prior to the imaging. Results: Overall, bilateral regions showed greater gray and white matter volume/integrity measures that were associated with better naming performance on the two tasks. Left peri-Sylvian language regions and their right-hemisphere counterparts, plus left mid-frontal gyrus correlated with accuracy and/or negatively with response time (RT) on the naming tests. For each of four behavioral measures (ANT/BNT reaction time and accuracy) white matter density was correlated with better performance, that is, participants with greater white matter density tended to have greater accuracy and faster reaction times. Clusters of voxels with significant regression coefficients were found in temporal, frontal, parietal, occipital lobes and even brainstem. No voxels showed significantly greater white matter density in poorer compared to better namers. Fractional anisotropy maps derived from DTI showed robust positive correlations with ANT accuracy bilaterally in the temporal lobe and in right middle frontal lobe, as well as negative correlations with BNT RT, bilaterally, in the white matter within middle and inferior temporal lobes. Conclusion: We conclude that those older adults with relatively better naming skills can rely on right-hemisphere peri-Sylvian regions and pathways, in conjunction with left-hemisphere peri-Sylvian and mid-frontal regions, to achieve their success. Significance: Our findings are consistent with those of Wierenga et al., 2008, and support Cabeza's (2002) model of hemispheric asymmetry reduction in older adults (HAROLD). They align nicely, as well, with the proposal by Wingfield and Grossman (2006) that regions peripheral to the core traditional left-hemisphere peri-Sylvian language areas support language processing in older adults. Relative sparing of mid-frontal gyri, moreover, permits solid Executive Function engagement in lexical retrieval. References: Cabeza, R. (2002). Hemispheric asymmetry reduction in older adults: the HAROLD model. *Psychology and Aging*, 17, 85-100. Wierenga, C.E., Benjamin, M., Gopinath, K., Perlstein, W., Leonard, C.M., Gonzalez Rothi, L.J., Conway, T., Cato, M.A., Briggs, R., & Crosson, B. (2008). Age-related changes in word retrieval: Role of bilateral frontal and subcortical networks, *Neurobiology of Aging*, 29, 436-451. Wingfield, A., & Grossman, M. (2006). Language and the aging brain: Patterns of neural compensation revealed by functional brain imaging. *Journal of Neurophysiology*, 96, 2830-2839.

103. Autonomic Nervous System and Aphasia. Y. Tanaka (1), M. L. Albert (2), K. Fujita (3), C. Nonaka (4), M. Miyazaki (5), E. Yokoyama (6). (1) Tanaka Clinic, Nara, Japan, (2) Neurology, VA Boston Healthcare System/Boston University

Medical School Boston, US. (3) Department of Internal Medicine, Sakakibara Onsen Hospital, Japan. (4) C. Nonaka, Department of Neuropsychology, Sakakibara Onsen Hospital, Mie, Japan. (5) M. Miyazaki, Neurology, Ise Keiyu Hospital, Mie, Japan. (6) E. Yokoyama, Akita Prefectural Center of Rehabilitation and Psychiatric Medicine, Akita, Japan.

Objectives. Autonomic nervous system (ANS) function has not been sufficiently explored in aphasia. Previously, we found that propranolol improves naming in aphasia. In the present study we ask: 1) Does propranolol affect fluent and nonfluent aphasia equally? 2) Does propranolol improve auditory comprehension, as well as naming, in aphasia? 3) At the same time that naming and verbal fluency improve, is there a concomitant measurable change in autonomic nervous system function? Subjects and Methods. 10 Ss with mild to moderate aphasia; 5 with Broca's aphasia (mean age: 60.2; range: 45-70); 5 with Wernicke's aphasia (mean age 68.0; Range: 58-71). The test battery consisted of the Boston Naming Test (BNT), two tests of auditory comprehension (yes/no and response to oral commands), and measurements of heart rate and anxiety. All Ss received baseline testing, followed one week later by pre-treatment testing. A third test session was carried out 90 minutes after administration of 10 mg of propranolol; and a fourth test (7days later). Results. In both groups following treatment the BNT score was significantly improved and the heart rate was significantly reduced. Additionally, in the Wernicke group, significant improvement was found with responses to oral commands. No change in anxiety score was found in either group. One week later, all scores returned to baseline. Conclusions. 1) Propranolol improves naming performance equally in Broca's and Wernicke's aphasia. 2) Propranolol improves auditory comprehension in Wernicke's aphasia. 3) At the moment of improvement in language performance, heart rate (a measure of the effect of propranolol on autonomic system function) decreases, but anxiety level remains unchanged. Autonomic nervous system function in aphasia deserves further exploration.

104. Generalization and maintenance in a treatment for phonologic alexia: what can fMRI tell us?

E.H. Lacey (1, 2), S.F. Snider (1), S.N. Lott (1), R.B. Friedman (1). (1) Center for Aphasia Research and Rehabilitation, Georgetown University Medical Center, Washington, DC, US (2) Interdisciplinary Program in Neuroscience, Georgetown University, Washington, DC, US.

Background. Studies of persons with aphasia before and after intervention not only help to improve the treatments, but also can provide valuable insights into the neural underpinnings of language. One area of active research in aphasia treatment is generalization of treatment effect. Many single-word treatments do not generalize, but many patients who need treatments at the single word level find higher-level treatments too difficult. The current study reports behavioral and fMRI results for patient TJN, a person with phonologic alexia (PhA), who showed unexpected generalization in a treatment focusing on reading single functor words. PhA is an acquired reading disorder characterized by an inability to read pseudowords (PWs). Reading PWs requires the use of the direct route between orthography and phonology, which is damaged in phonologic alexia. Many PhA patients also have difficulty reading abstract words and functors (function words such as conjunctions and prepositions that are low in semantic value). Methods TJN, a 45-year-old woman with 16 years of education, suffered a left middle cerebral artery stroke resulting in a lesion encompassing left posterior frontal and temporo-parietal regions, 2 years prior to the study. She participated in a behavioral treatment in which she practiced reading functors in isolation and then within the context of concrete phrases (CCP). Reading of sentences containing the trained and untrained words was tested before treatment, after training of functors in isolation and after CCP training. TJN also participated in fMRI scanning sessions pre-treatment, post-treatment and at treatment maintenance (8 months post-treatment). In the scanner, she was asked to read functor words flanked by either concrete words or non-pronounceable letterstrings. Results and Conclusions Patient TJN improved significantly over baseline reading of trained functors after treatment. Unexpectedly, untrained functors in sentences also improved, but only after she underwent the CCP training. These results suggest that it may be necessary to engage syntactic structure through training in context in order for generalization of single word treatments to occur. 8 months post-treatment, reading of untrained functors in sentences returned to baseline levels of accuracy. Reading of trained functors in sentences maintained. Imaging results show functor reading post-treatment was associated with greater perilesional activation and activation in inferior/middle temporal and occipital areas associated with reading in controls. Activation in LH areas was also greater for the post-treatment scan as compared to the maintenance scan. These findings are consistent with others in the literature suggesting that LH language areas are particularly suited for performing language tasks and that recruitment of these areas, even in patients 2 years post-stroke, is associated with more effective language use. These results also suggest that the return to baseline performance that is often seen in aphasia treatments may be associated with a drop-off in LH activation. A second patient with phonologic alexia is currently undergoing treatment and scanning sessions in this same protocol. An interim scanning session between the isolation and CCP training with this second patient may provide more data on functional reorganization associated with generalization to untrained functors.

105. Enhanced speech perception capabilities in blind listeners: an example of cross-modal plasticity involving fusiform gyrus and primary visual cortex.

S. Dietrich (1), H. Ackermann (1), I. Hertrich (1). (1) University of Tuebingen, Tuebingen, Germany.

Blind individuals may acquire the skill of understanding ultra-fast synthetic speech at a rate of up to 25 syllables per second (syl/s), an accomplishment by far exceeding the maximum performance level of normal-sighted listeners (8 - 10 syl/s). To further elucidate the cerebral mechanisms supporting these capabilities, hemodynamic responses to moderately fast (8 syl/s) and ultra-fast synthetic speech (16 syl/s) were registered in eleven blind and seven normally sighted subjects, using functional magnetic resonance imaging (fMRI). Furthermore, individual performance of ultra-fast speech perception (percentage of

correctly reproduced words) was determined (sentence repetition task). These behavioral data (range of performance in blind individuals 0 - 90%, in controls less than 20%) served as a covariate for the analysis of BOLD responses during listening to ultra-fast speech (versus baseline). (i) Behavioral performance was found to correlate significantly with hemodynamic activation at the level of rostral-caudal parts of middle temporal gyrus (MTG) and superior temporal sulcus (STS) of both hemispheres, left-hemisphere inferior frontal gyrus (IFG), ipsilateral fusiform gyrus (FG), and contralateral primary visual cortex (VI). (ii) Based upon ROI analyses, the hemodynamic responses of IFG, FG and VI to the two speech rate conditions were plotted against individual performance of understanding ultra-fast speech. In blind participants, activation both of IFG and FG increased in parallel with ultra-fast speech comprehension proficiency. During application of moderately fast speech stimuli, a similar linear relationship was restricted to FG. By contrast, VI activation inclined – like a training curve - along with behavioral performance up to a medium level, but then began to decrease in the blind subjects with the highest percentage of correct word repetitions. (iii) The time course of hemodynamic responses in “ultra-fast speech experts” exhibited different trajectories across ROIs. As compared to auditory cortex, IFG activation showed a similar onset, but both a delayed peak and a delayed offset by some seconds, reflecting, presumably, phonological working memory processes within the speech generation system. At the level of VI, a more or less prototypical time course of the BOLD response could be observed - similar to that in auditory cortex, but at a delay of 2-3 s. Finally, FG and VI displayed similar temporal trajectories of hemodynamic activation. This investigation, based upon a group of blind subjects, confirms and extends a preceding single-case study (Hertrich I, Dietrich S, Moos A, Touvain J, Ackermann H. *Neurocase* 2009;15:163-170). Obviously, blind people are able to expand their speech processing capabilities by recruiting (some parts of) the visual system. FG seems to represent an important phonological interface between auditory and visual input, on the one hand, and lexical data structures, on the other. The role of VI is less clear so far and could be bound to either higher-order lexical operations or earlier perceptual stages, e.g., in terms of reduced backward masking effects.

106. Neural changes underlying the acquisition of conceptual knowledge in a damaged brain. A.

Pillon (1), and B. Léonard (1). (1) Université catholique de Louvain, Louvain-la-Neuve, Belgium and Fonds National de la Recherche Scientifique, Belgium.

It is well known for over a century that individuals suffering cognitive disorders consecutive to focal brain damage may show partial if not complete recovery of the impaired functions several months or even years following injury. Understanding the plastic changes involved in successful recovery would be essential for the development of theoretically motivated rehabilitation methods. In this study, we focused on the recovery of conceptual representation and processing. We investigated with functional magnetic resonance imaging (fMRI) changes in the distribution of cortical activity associated with training-induced acquisition of new conceptual knowledge in an individual who had damage to the conceptual processing neural network. We asked which alternative neural structures were susceptible to be recruited for representing new conceptual knowledge and, more specifically, whether such recruitment was constrained by the domain (living vs. nonliving) of conceptual knowledge. A post-encephalitis female patient, DL, who presented an extensive left temporal damage and was in the chronic stage of recovery, as well as nine neurologically intact control subjects matched to the patient for gender and education, participated in the study. We presented the patient with an intensive conceptual therapy aimed at (re)learning the semantic properties of 10 plant (living domain) and 10 artifact (nonliving domain) items whose knowledge was impaired. The control conditions included impaired items from another conceptual domain, i.e., animals, that were either not trained at all (n=10) or lexically trained (n=10). The behavioral effects of the therapy were assessed with a word picture verification and a naming task (from which a composed semantic score was drawn) presented before the therapy, just after it was completed, and one and three months after its completion. Cortical activity associated with the processing of the same items was also measured with fMRI at these four time points during a semantic category monitoring task, which the patient could perform with high accuracy and normal speed for the selected items. The control subjects were presented the same activation task twice, with a three-month interval between both sessions, which corresponded to the duration of the therapy in DL. The fMRI data from the healthy subjects were used to (i) control for the test-retest activation effects in DL; (ii) characterize the function (domain-general vs. domain-specific) of the areas showing activation changes in DL. After the therapy, the patient's conceptual knowledge (semantic score) significantly improved for both the plant and artifact items that were trained, while no significant improvement was found for the control conditions. Improved conceptual knowledge was associated with increased activation in the left parieto-occipital junction for the plant items and in the left middle occipital gyrus for the artifact items. These regions were associated with domain-specific conceptual processing in all or some of the healthy subjects of our study. These findings suggest that the plastic changes underlying the acquisition of new conceptual knowledge in the condition of a damaged conceptual processing system are constrained by the conceptual domain of knowledge and by the capacity of the intact structures to assume domain specific functions.

107. Lesion Correlates of Aphasia Signs and Syndromes. *Nina F. Dronkers (1,2), Juliana V. Baldo (1), And Turken (1), Jenny Ogar (1), David Wilkins (1), Carl Ludy (1), Analia Arevalo (1), and Robert T. Knight (3). (1) VA Northern California Health Care System, Martinez, CA, US (2) University of California, Davis and University of California, San Diego, US (3) University of California, Berkeley, US.*

Knowledge of the brain regions associated with the different symptoms of aphasia has changed over the years since the advent of superior brain imaging techniques. Differences in lesion localization between acute and chronic patients have also become

apparent with most current models being largely derived from patients in the acute stage of their illness. The present study evaluated the brain lesions associated with the different signs and syndromes of aphasia in a large group of carefully-controlled chronic aphasic stroke patients to evaluate these brain-behavior relationships. 154 patients had suffered a single left hemisphere infarction with a residual speech or language deficit. All were right-handed and native English-speaking with no prior neurological or psychiatric history, and were evaluated with the Western Aphasia Battery (WAB) more than one year post onset. All had undergone structural neuroimaging and patients' lesions were computer-reconstructed and normalized into MNI space. Voxel-based lesion symptom (VLSM) analyses were then performed on the data to elicit regions most highly associated with performance on the various WAB subtests as well as with the different aphasia syndromes. VLSM and regression analyses revealed the same general pattern of brain-behavior relationships as those derived from acute data, but also with some fundamental differences. Lesions in chronic Broca's aphasia involved primarily deeper areas than Broca's area and included the insula and underlying white matter. Lesions in chronic Wernicke's aphasia often included Wernicke's area, but the key region appeared to be the middle temporal gyrus. In chronic conduction aphasia, the area of common infarction was the inferior parietal cortex and posterior superior temporal gyrus. VLSM results from individual subtest analyses revealed that these deficits were better predictors of brain-behavior relationships than aphasia syndromes. For example, repetition skills were affected in several different types of aphasia, but were consistently associated with lesions in the posterior superior temporal gyrus. Fluency was associated with the insula and superior longitudinal fasciculus while comprehension ability was significantly impaired after middle temporal gyrus lesions, regardless of aphasia type. These results from a large group of chronic aphasic patients yielded areas sometimes in agreement, but sometimes in disagreement, with classic neurobiological models. In addition, analysis of the individual deficits observed in aphasic patients yielded more detailed information regarding brain-behavior relationships than did aphasia syndromes. Such large-scale studies indicate that the identification of very specific behavioral deficits and their neuroanatomic correlates can lead to more effective mapping of language functions in the brain.

Conference Registration

Conference Registration Fees		
	Early (May 15 – September 1 st 2009)	Late (September 1 st – October 15 2009)
Regular	150 USD	225 USD
Postdoctoral scholars	65 USD	115 USD
Students	45 USD	95 USD

Registration fees include access to all conference sessions, breakfast pastries in the morning, morning and afternoon coffee breaks, an evening reception on October 15th, and all conference materials.

Student Eligibility

To register for the conference as a student (graduate students, medical students, residents, fellows), you must submit a letter from your department to confirm your student status and expected date of graduation. Letters can be mailed to the NLC2009 Registrar (address appears below), emailed to registration@neurolang.org or faxed to (773) 702-2482.

Cancellation Policy

Written requests for refunds are subject to a cancellation fee of \$10 before the end of the early registration period (Sept. 1st 2009). Between September 2nd and September 30th 2009, a cancellation fee of 50% will be applied. No refunds will be processed after October 1st 2009.

Registration Inquiries

NLC2009 Registrar, Department of Neurology, The University of Chicago, 5481 S. Maryland Ave. MC-2030, Chicago IL, USA, 60637. Phone: (773) 834-7770, Fax: (773) 702-2482; registration@neurolang.org

Should you need an invitation letter to apply for a visa, please contact: registration@neurolang.org

Conference Venue

The first Neurobiology of Language Conference will be held at the Chicago Marriott Downtown Magnificent Mile. The Chicago Marriott Downtown is in the heart of it all. Situated on Michigan Avenue's Magnificent Mile among world-class shopping, restaurants, and entertainment, this luxurious Chicago, Illinois hotel is within walking distance to the Windy City's top attractions, including Navy Pier, Sears Tower, Shedd Aquarium, Millennium Park, Theater and Museum Districts. Chicago promises to provide a most enjoyable setting for the meeting.



Hotel information:

540 North Michigan Avenue, Chicago, Illinois 60611 USA.

Phone: 1-312-836-0100

Toll-free: 1-800-228-9290

Website: <http://www.marriott.com/hotels/travel/chidt-chicago-marriott-downtown-magnificent-mile/>

Directions from O'Hare Airport (ORD)

Phone: 1 773 686 2200

Hotel direction: 15 miles SE

Driving directions: Take I-190 East into I-90 (Kennedy Expressway) East to the Ohio Street Exit (50B). Ohio Street is a one-way street eastbound. Take Ohio Street to Rush Street. Turn right on Rush for hotel entrance. Estimated taxi

fare: 40.00 USD (one way)

Directions from /Midway Airport (MDW)

Phone: 1 773 838 0600

Hotel direction: 12 miles NE

Driving directions: Take Cicero Avenue north to I-55 North into I 90/94 West, (signs say To Wisconsin). Take Ohio St Exit (50B), Ohio Street is a one-way street eastbound. Turn right on Rush for hotel entrance. Estimated taxi fare: 30.00 USD (one way).

Accommodations

Rooms availability is limited at the **Marriott Downtown Hotel**, the Conference venue, be prompt to make your reservation. The Conference price (**\$269/night**) applies for the following dates: October 14, 15 and 16. The best way to make a reservation is to use the Marriott's toll free number: 1-800-228-9290.

A block of rooms has been reserved for conference attendees at the **Seneca Hotel**. The Conference rate is **\$139/night**. The Conference price applies for the following dates: October 14 and 15. The Seneca Hotel is located on 200 E Chestnut Street, Chicago, 60611, just a block off Michigan Avenue, and only 0.5 miles from the Conference venue. To make a reservation, call the hotel at 312-787-8900 or 1-800-800-6261 and ask for the Neurobiology of Language Conference rate.

The following hotels are located at a walking distance of the Marriott Downtown Hotel. Alternatively, you may use search engines to find available rooms in the downtown Chicago area, such as Trip Advisor: <http://www.tripadvisor.com/>.

Wyndham Hotel

633 N St. Clair, Chicago IL, 60611
(312) 573-0300
www.wyndham.com
0.1 miles from Marriott
From **\$216/night**

Inn of Chicago

162 E Ohio St, Chicago IL, 60611
(312) 787-3100
www.innofchicago.com
0.1 miles from Marriott
From **\$214/night**

Comfort Suites Chicago

320 N Michigan Ave, Chicago IL, 60601
(312) 376-1887
www.comfortsuites.com
0.4 miles from Marriott
From **\$239/night**

The Wit Hotel

201 N State St, Chicago IL, 60601
(312) 467-0200

www.thewithhotel.com

0.5 miles from Marriott

From **\$229-249/night**

Congress Hotel

520 S Michigan ave., Chicago IL, 60605
(312) 212-8192

<http://www.congressplazahotel.com>

1.2 miles from Marriott

From **\$149/night**

Tremont Hotel

100 E Chestnut st., Chicago IL, 60611
(312) 751-1900

<http://www.tremontchicago.com>

0.5 miles from Marriott

From **\$180/night**

Club Quarters

75 E Wacker Drive, Chicago IL, 60601
(312) 357-6400

www.clubquarters.com

0.5 miles from Marriott

From **\$202/night**

Holiday Inn Express

640 N Wabash ave., Chicago IL, 60611
(312) 787-4030

www.hiexpress.com

0.2 miles from Marriott

From **\$205/night**

Central Loop Hotel

W Adams, Chicago IL, 60603
(212) 515-3060

www.centralloophotel.com

1.2 miles from Marriott

From **\$215/night**

Conference Organization

The meeting is being developed by an international organizing committee, under the direction of Professor Steven L. Small and Dr. Pascale Tremblay of The University of Chicago. We would like to thank the members of the Organizing Committee and of the Local Committees, the members of the Abstract Review Committee, as well as our sponsors.

Organizing Committee

Jeffrey Binder, M.D., Medical College of Wisconsin, USA
Sheila Blumstein, Ph.D., Brown University, USA
Laurent Cohen, M.D., Hôpital de la Salpêtrière, France
Angela Friederici, Ph.D., Max Planck Institute, Germany
Vincent Gracco, Ph.D., McGill University, Canada
Peter Hagoort, Ph.D., Max Planck Institute, Netherlands
Marta Kutas, Ph.D., The University of California, San Diego, USA
Alec Marantz, Ph.D., New York University, USA
David Poeppel, Ph.D., New York University, USA
Cathy Price, Ph.D., University College London, UK
Kunio Sakai, Ph.D., Tokyo University, Japan
Riitta Salmelin, Ph.D., Helsinki University of Technology, Finland
Bradley Schlaggar, M.D., Ph.D., Washington University, USA
Richard Wise, M.D., Ph.D., Imperial College, London, UK

Local Program Committee

Michael Andric, The University of Chicago
Anthony Dick, The University of Chicago
Steven L. Small, The University of Chicago
Pascale Tremblay, The University of Chicago

Local Organizing Committee

Blythe Buchholz, The University of Chicago
Margaret Flynn, The University of Chicago
Lydia Madrigal, The University of Chicago
Eva Mok, The University of Chicago
Julia Sheffield, The University of Chicago
Roma Siugzdaite, The University of Chicago
Pascale Tremblay, The University of Chicago

Abstract Review Committee

Andrea Santi, Department of Linguistics, McGill University, Canada and Department of Neuropsychology, Max Planck Institute for Human Cognitive and Brain Sciences, Germany.
Anjali Raja, Rotman Research Institute of Baycrest Centre, University of Toronto, Toronto Canada.
Anthony Dick, The University of Chicago, Department of Neurology, US.
Ariane Rhone, Department of Linguistics, University of Maryland, US.
Arielle Borovsky, Department of Psychology, Stanford University, US.

Corrado Corradi-Dell'Acqua, Cognitive Neuroscience Sector, International School for Advanced Studies, (SISSA), Trieste, Italy.
Debra Titone, Department of Psychology, McGill University, Canada.
Doug Davidson, Max Planck Institute for Human Cognitive and Brain Sciences, Germany.
Efrat Pauker, School of Communication Sciences and Disorders, McGill University, Canada.
Ekaterini Klepousniotou, Institute of Psychological Sciences, Faculty of Medicine, University of Leeds, UK.
Elena Zinchenko, The University of Chicago, Department of Psychology, US.
Eugenia Solano-Castiella, Max Planck Institute, Germany.
Eva Mok, The University of Chicago, Department of Neurology, US.
Greig de Zubicaray, Centre for Magnetic Resonance, University of Queensland, Brisbane, Australia.
Henri Cohen, Cognitive Psychology and Neuroscience Laboratory, UMR-8189, Université Paris Descartes-CNRS, France.
Hugh Rabagliati, Department of Psychology, New York University, US.
Inna Fishman, The Salk Institute for Biological Studies, La Jolla, US.
Isabelle Deschamps, School of Communication Sciences and Disorders, McGill University, Canada.
Jamie Reilly, Department of Communicative Disorders, University of Florida, US.
Jens Brauer, Max Planck Institute for Human Cognitive and Brain Sciences, Germany.
Jeremy Skipper, Sackler Institute for Developmental Psychobiology, Cornell University, US.
Johanna Barry, Max Planck Institute for Human Cognitive and Brain Sciences, Germany.
Johanna Vartiainen, Brain Research Unit of the Low Temperature Laboratory at Helsinki University of Technology, Finland.
Jonas Obleser, Max Planck Institute for Human Cognitive and Brain Sciences, Germany.
Jonathan Peelle, MRC Cognition and Brain Sciences Unit, Cambridge, UK
Kelly Anne Barnes, Washington University School of Medicine, US.
Kirsten Weber, Radboud University Nijmegen, Donders Institute for Brain, Cognition and Behaviour, Donders Centre for Cognitive Neuroimaging, The Netherlands.
Laura Motyka Joss, DePaul University, Department of Psychology, US.
Leonardo Femandino, Department of Psychology, University of California, Los Angeles, US.
Mandy J. Maguire, Behavioral and Brain Sciences, Callier Center for Communication Disorders, University of Texas at Dallas, US.
Marc Sato, Centre national de la recherche scientifique, France.
Matt Davis, MRC Cognition and Brain Sciences Unit, Cambridge, UK.
Matthias Schlesewsky, Department of English and Linguistics, Johannes Gutenberg-Universität, Germany.
Mia Liljeström, Brain Research Unit of the Low Temperature Laboratory at Helsinki University of Technology, Finland.
Michael Andric, The University of Chicago, Department of Neurology, US.
Minna Lehtonen, Low Temperature Laboratory, Helsinki University of Technology, and Dept. of Psychology, Åbo Akademi University, Finland.
Monika Molnar, School of Communication Sciences and Disorders, McGill University, Canada
Neha Khetrapal, Center of Excellence "Cognitive Interaction Technology", University of Bielefeld, Germany.
Nina Kraus, Northwestern University, Communication Sciences, Neurobiology and Physiology, Otolaryngology, US.
Pascale Tremblay, The University of Chicago, Department of Neurology, US.
Peter Indefrey, Max Planck Institute for Psycholinguistics, Germany.
Philip J. Monahan, Department of Linguistics, University of Maryland, US.
Philipp Kanske, Department of Clinical and Cognitive Neuroscience, Central Institute of Mental Health, Germany.
Roma Siugdaite, The University of Chicago, Department of Neurology, US.
Shari Baum, School of Communication Sciences and Disorders, McGill University, Canada.
So-One Hwang, Department of Linguistics, University of Maryland, US.
Suzanne Dikker, Department of Linguistics, New York University, US.
Uri Hasson, Center for Mind/Brain Sciences, The University of Trento, Italy.
Venu Balasubramanian, Seton Hall University, South Orange, US.
Vincent Gracco, School of Communication Sciences and Disorders, McGill University, Canada and Haskins Laboratory, New Haven, US.
Xing Tian, Department of Psychology, New York University, US.

Sponsors

The symposium is co-sponsored by the Center for Integrative Neuroscience and Neuroengineering Research (CINNR), the Human Neuroscience Laboratory and Department of Neurology of The University of Chicago, and by the international journal *Brain and Language*.

Author Index

Legend: P = Poster Number; S = Slide session; K = Keynote lecture; D = Discussion Panel. Th: Thursday October 15; F: Friday, October 16. **Example:** *Smith, J. P119, F. Poster 119 on Friday.*

A

Abel, S.: P31, F
Aboitiz, F.: P12, Th
Ackermann, H.: P55, Th; P105, F
Adorni, R.: P27, F
Agosta, F.: P97, Th
Alario, F.-X.: P36, F
Albert, M.L.: P101, F; P103, F
Alcocer, P.M.: P2, F; P12, F
Almor, A.: P19, Th
Altarelli, I.: P26, F
Amadon, A.: P67, Th
Amberber, A.M.: P47, Th
Ambrose, N.G.: P32, F
Amsari, D.: P18, F
Anand, R.: P20, Th
Andersen, S.: P95, F
Andersson, A.: P59, Th
Andric, M.: P61, F
Antonello, D.: P98, F
Arbib, M.A.: P85, F
Arevalo, A.: P106, F
Arnoldussen, A.: P3, Th
Arzouan, Y.: P1, Th
Asano, E.: P34, F
Ashby, J.: P61, Th
Avants, B.: P100, F
Ayano, S.: P95, Th

B

Bacon, B.A.: P29, F
Bakkour, A.: P100, F
Balasubramanian, V.: P85, Th
Baldo, J.V.: P89, F; P107, F
Bamdad, M.: P90, F
Barbaro, N.M.: P5, F; S3, Th
Barnhart, A.: P84, Th
Barrett, A.: P85, Th
Basirat, A.: P51, F
Basso, G.: P37, F
Batterink, L.: P78, F
Baum, S.: P47, F; P49, Th; P70, F; P72, F
Baumgärtner, A.: P40, F
Beauchamp, M.: P10, F
Bedny, M.: P58, F
Beeson, P.: P95, F
Beeson, P.M.: P71, Th; P82, Th; P97, F
Béland, R.: P29, F
Bemis, D.K.: P9, Th
Berent, I.: P38, Th
Berentsen, S.: P35, F
Bergelson, E.: P15, F
Bermo, M.S.S.M.: P29, Th

Bhagat, S.: P46, Th
Bidelman, G.: P36, Th
Bihler, S.: S5, F
Binder, J.R.: P3, Th; P15, Th; P35, F; S2, F
Biondi, C.: P53, F
Birbaumer, N.: S2, Th
Boas, D.: P37, Th
Boiteau, T.W.: P19, Th
Bonakdarpour, B.: P33, F; P97, F
Bonifazi, S.: P53, F
Bonner, M.F.: P100, F
Bornkessel-Schlesewsky, I.: P69, Th; S6, F
Borowsky, R.: P11, Th
Bortfeld, H.: P37, Th
Boucher, V.J.: P75, F
Boulenger, V.: P4, F; P52, F; S4, F
Boureau, Y.: P88, Th
Bourguignon, N.: P51, Th; P77, Th
Bradley, C.: P22, F
Bradley, E.: P22, F
Bradlow, A.: P41, Th
Brajot, F.-X.: P47, F
Braze, D.: P78, Th
Brecher, A.: S1, F
Breitenstein, C.: S1, Th
Brier, M.: P2, Th
Briner, S.W.: P18, Th
Brinkley, J.F.: P39, F
Brisebois, A.: P51, F
Brodeur, M.B.: P86, F
Brown, S.: P28, F
Brownsett, S.L.E.: P17, F
Brunetti, E.: P12, Th
Brysbart, M.: P57, F
Bufalari, I.: P65, F
Bunge, S.: P89, F
Burlle, B.: P36, F
Burraco, A.B.: P45, F
Busan, P.: P65, F
Buxbaum, L.J.: P56, F

C

Cagy, M.: P96, Th
Campioni, G.C.: P54, F
Cantagallo, A.: P53, F
Cantiani, C.: P98, Th
Capasso, R.: P37, F
Caplan, D.: P84, F
Caramazza, A.: P58, F
Carrasco, H.: P52, Th
Carreiras, M.: P73, Th
Casasanto, D.: P67, F
Cattaneo, L.: P51, F

Ceponiene, R.: P35, Th
Chambers, S.: P3, Th
Chan, A.H.D.: P74, F
Chandrasekaran, B.: P34, Th; P74, F
Chang, E.F.: P5, F; P11, F
Chang, S.: P41, F
Chapman S.B.: P20, Th
Chauvel, P.: P13, F
Chen, H.C.: P14, Th
Chen, J.-K.: P63, F
Chen, Y.: P40, Th
Chiarello, C.: P65, Th
Cho, H.: P71, Th; P97, F
Choo, A.: P32, F
Chryssikou, E.G.: P87, F
Clark-Cotton, M.R.: P101, F
Clark, R.: P10, Th; P80, F
Cobia, D.: P94, F
Coccia, M.: P53, F
Coffey-Corina, S.: P42, Th
Cohen, H.: P50, F; P85, Th
Cohen, L.: P67, Th; P83, Th
Coltheart, M.: P47, Th
Conant, L. L.: P15, Th
Conant, L.L.: P3, Th
Conboy, B.: P54, Th
Conklin, C.J.: P29, Th
Copeland, L.: P70, F; P47, F
Corina, D.P.: P39, F
Coslett, H.B.: S1, F
Craighero, L.: P53, F
Crain, S.: P47, Th
Crone, N.E.: P11, F; S3, Th
Cummie, J.: P11, Th
Cummings, A.: P35, Th
Curran, T.: P4, Th

D

D'Ausilio, A.: P65, F
Dakka Volta, R.: P54, F
David, S.V.: P11, F
Davidson, D.J.: P45, Th
Davis, M.: P40, Th
Davis, M.H.: P8, Th; P30, F; P33, Th; P57, F; P72, Th; P79, F
de Vries, M.: S1, Th
de Zubicaray, G.: P7, Th
Deblieck, C.: S3, F
Debrulle, J.B.: P86, F
Decety, J.: P24, Th
Dehaene, S.: P67, Th; P83, Th; P88, Th
Dell, G.S.: S1, F
DeMarco, A.: P29, Th
Démonet, J.F.: P13, F; P75, Th

den Ouden, D.B.: P55, F
 Dering, B.: P74, Th
 Desai, R.H.: P3, Th; P15, Th; S2, F
 Deschamps, I.: P47, F; P48, F; P72, F
 Detwiler, L.: P39, F
 Devauchelle, A.-D.: P88, Th
 Dhanjal, N.: P48, Th
 Dick, A.S.: P28, Th
 Dickerson, B.: P100, F
 Dietrich, S.: P104, F
 Dikker, S.: P89, Th
 Dillon, B.: P19, F
 Dillon, B.W.: P2, F
 Dobel, C.: P43, Th
 Dogil, G.: S2, Th
 Dole, M.: P7, F
 Dow, M.: P94, Th
 Dressel, K.: P31, F
 Dronkers, N.F.: P89, F; P97, Th:
 P107, F
 Drury, J.E.: P51, Th; P77, Th
 Dufau, S.: P36, F
 Dunabeitia, J.A.: P73, Th
 Durvasula, K.: P22, F

E

Eason, R.J.: P8, Th:
 Ebersole, J.: P81, F:
 Eden, G.: P80, Th:
 Edward, C.: S3, Th:
 Egera, E.: P67, Th:
 El Ghaoui, L.: P79, Th:
 Enriquez-Geppert, S.: P43, Th:
 Erb, M.: P55, Th:
 Escobar, J.: P24, Th:
 Esopenko, C.: P11, Th:
 Ettlinger, M.: P41, Th:
 Eulitz, C.: P20, F:
 Eviatar, Z.: P6, Th:

F

Fadiga, L.: P65, F; DB, F
 Fanning, J.: P59, Th:
 Fargier, R.: S4, F:
 Farmer, H.: P59, F
 Farmer, T.A.: P89, Th
 Faro, S.: P29, Th
 Faseyitan, O.: S1, F
 Faulkner, A.: P26, F
 Faust, M.: P1, Th
 Fava, E.: P37, Th
 Fecteau, S.: P99, F
 Federmeier, K.D.: P91, F
 Fedorenko, E.: P26, Th
 Feess, D.: P27, Th
 Felder, V.: P20, F
 Ferjan, N.: P63, F
 Fernandino, L.: P17, Th
 Festa, J.: P98, F
 Figueroa, V.: P1, F
 Fillmore, P.T.: S4, Th
 Fisher, S.: K4, F

Fix, S.C.: P33, F
 Flinker, A.: P5, F; P11, F; S3, Th
 Flöel, A.: S1, Th
 Fonteijn, H.M.: P31, Th
 Frak, V.: P50, F
 Franca, A.: P96, Th
 França, A.I.: P53, Th
 Frederic, A.D.: P39, Th
 Frenck-Mestre, C.: P52, Th
 Friederici, A.D.: P71, F
 Friedman, R.B.: P103, F
 Friedmann, N.: P87, Th
 Friedrich, M.: P71, F
 Frim, D.L.: P81, F
 Frye, R.E.: P88, F
 Fujita, K.: P103, F
 Fulbright, R.K.: P78, Th

G

Gaebler, M.: P58, Th
 Gage, N.M.: S4, Th
 Gagnepain, P.: P40, Th
 Gandour, J.: P36, Th
 Garagnani, M.: P16, F; P52, F
 García-Bellido, P.: P45, F
 Garcia-Sierra, A.: P54, Th
 Garnsey, S.: P91, Th
 Garnsey, S.M.: P13, Th
 Gaskell, G.: P40, Th
 Gentilucci, M.: P54, F
 Geranmayeh, F.: P17, F
 Gerloff, C.: P43, Th
 Gervain, J.: P38, Th
 Gesualdi, A.: P96, Th
 Gianelli, C.: P54, F
 Gilbert, A.: P75, F
 Glauche, V.: S5, Th
 Glenberg, A.M.: P51, F
 Goldinger, S.: P84, Th
 Goldstein, A.: P1, Th
 Gonzalez, R.: P9, F
 Goral, M.: P101, F
 Gorno-Tempini, M.L.: P97, Th
 Gouws, A.: P40, Th
 Goyette, M.: P50, F
 Grabski, K.: P51, F
 Gracco, V.L.: P47, F; P48, F; P70, F;
 P72, F
 Graves, W.W.: P15, Th
 Grillo, N.: P99, Th
 Grindrod, C.M.: P22, Th
 Grodd, W.: P55, Th
 Grodzinsky, Y.: P90, Th: DA, Th
 Grossberg, S.: P6, F
 Grossman, M.: P10, Th: P32, Th:
 P80, F; P93, F; P100, F
 Groth, K.: P76, Th
 Guasti, M.T.: P98, Th
 Gugler, M.: P58, Th
 Gunawadana, D.: P10, Th; P80, F;
 P93, F

Guo, T.: P57, Th

H

Hadar, U.: P87, Th
 Hagoort, P.: P31, Th: S5, F; P67, F;
 DA, Th
 Hamilton, A.C.: P25, F
 Hancock, A.: P90, F; P44, F
 Hansen, B.C.: P60, F
 Hart, J.: P20, Th:
 Hasegawa, M.: P73, F:
 Hattori, N.: P95, Th:
 Hauk, O.: P38, F; P52, F; P72, Th
 Hawes-Ebersole, S.: P81, F
 Haye, A.: P9, F:
 Heath, R.: P79, Th:
 Henry, M.L.: P82, Th; P97, F
 Henson, R.: P72, Th:
 Hernandez, A.E.: P58, Th:
 Hertrich, I.: P104, F:
 Hestvik, A.: P22, F
 Hickok, G.: DB, F
 Hird, K.: P43, F
 Hoen, M.: P4, F; P7, F
 Holloway, I.D.: P18, F:
 Hori, T.: P96, F
 Horie, R.: P73, F
 Hornickel, J.: P34, Th
 Horwitz, B.: P41, F
 Howard, M.: P1, F
 Hsu, C.-H.: P64, Th
 Hu, X.: P55, Th
 Huber, W.: P31, F; P83, F; P92, F
 Hummel, F.: P43, Th
 Humphries, C.: S2, F
 Huq, M.: P2, Th
 Hurtado, E.: P24, Th: P9, F
 Hwang, S.: P3, F
 Hyun, J.: P101, F

I

Iacoboni, M.: S3, F
 Ibañez, A.: P9, F; P24, Th
 Idsardi, B.: P1, F
 Idsardi, W.: P3, F; P15, F; P21, F
 Idsardi, W.J.: P12, F; P2, F
 Indefrey, P.: P45, Th
 Infantosi, A.: P96, Th
 Inokuchi, Y.: P95, Th
 Isenberg, A.L.: S4, Th
 Ito, K.: P73, F
 Itzhak, I.: P47, F; P72, F
 Ivanitsky, A.: P66, Th

J

Jackson, S.R.: P13, Th
 Jacquier, C.: P4, F
 Jäger, L.: P92, F
 Janssen, N.: P36, F
 Jarvis, E.D.: P44, Th
 Jax, S.A.: P56, F
 Jeannerod, M.: P50, F

Jemel, B.: P75, F
Jensen, E.: P12, F
Jilka, M.: P55, Th
Joanisse, M.F.: P25, F
Johnson, K.: P5, F
Johnsrude, I.S.: P33, Th
Joss, L.M.: P18, Th

K

Kaan, E.: P14, F
Kalm, K.: P79, F
Kanwisher, N.: P26, Th
Kappes, J.: P40, F
Kara, W.: P14, F
Karns, C.: P78, F
Kastrau, F.: P92, F; P83, F
Kätsyri, J.: P23, F; P24, F
Kawamura, M.: P96, F
Kawohl, W.: P92, F
Kazerounian, S.: P6, F
Keil, A.: P14, F
Kellmeyer, P.: P27, Th; P39, F; S5, Th
Kelly, S.D.: P60, F
Kerlin, J.R.: P8, F
Ketteler, D.: P83, F; P92, F
Ketteler, S.: P83, F; P92, F
Kielar, A.: P33, F
Kim, A.: P81, Th; P93, Th
Kim, D.-S.: P101, F
Kimberg, D.Y.: S1, F
King, R.: P97, F
Kingston J.: P61, Th
Kinno, R.: P96, F
Kirsch, H.E.: S3, Th
Kirsner, K.: P43, F
Klann-Delius, G.: P71, F
Klarman, L.: P54, Th
Klein, D.: P63, F
Kleinschmidta, A.: P67, Th
Klepousniotou, E.: P47, F; P68, F; P72, F
Knecht, S.: S1, Th
Knight, R.T.: P5, F; P11, F; P107, F; S3, Th
Kohrman, M.A.: P81, F
Kojima, S.: P95, Th
Komachi, M.: P95, Th
Koskinen, M.: S6, Th
Koyama, S.: P25, Th
Kraft, S.: P32, F
Krakauer, J.W.: P98, F
Kratovac, S.: P12, F
Kraus, N.: P34, Th
Krawczyk, D.C.: P2, Th
Kretzschmar, F.: P69, Th
Krishnan, A.: P36, Th
Kroll, J.F.: P57, Th
Krott, A.: P21, Th; P86, Th
Kuhl, P.: P46, Th
Kuhl, P.: P18, F; 42, Th; P50, Th; P54, Th

Kujala, T.: P77, F
Kümmerer, D.: P27, Th; S5, Th
Kuperberg, G.: P100, Th

L

Lacey, E.H.: P103, F
Laganar, M.: P42, F
Laganaro, M.: P46, F
Lai, V.T.: P4, Th
Laine-Hernandez, M.: P23, F
Lallier, M.: P74, Th; P75, Th
Landry, S.: P88, F
Lassonde, M.: P29, F
Lazar, R.M.: P98, F
Le Bas, J.F.: P75, Th
Lebedeva, G.C.: P46, Th
Lebib, R.: P21, Th; P86, Th
Lee, C.-L.: P91, F
Lee, J.-Y.: P85, F
Leech, R.: P48, Th
Lemle, M.: P96, Th
Léonard, B.: P105, F
Leonard, C.: P65, Th
Lewis, G.: P63, Th
Li, R.: P40, Th
Liegeois-Chauvel, C.: P13, F
Liljeström, M.: S6, Th
Lin, T.: P51, Th
Lin, Y.: P91, Th
Lindsay, S.: P40, Th
Liotti, M.: P28, F
Lipka, K.: P70, Th
Lipowski, K.: P2, Th
Liu, H.M.: P18, F
Liuzzi, G.: P43, Th
Lobos, A.: P24, Th
Longtin, C.-M.: P72, Th
López, W.: P12, Th
Lorusso, M.L.: P98, Th
Lott, S.N.: P103, F
Loucks, T.: P32, F
Loucks, T.M.J.: P22, Th
Loudermilk, B.C.: P39, F
Ludlow, C.L.: P41, F
Ludy, C.: P106, F
Lukyanchenko, A.: P12, F

M

Mader, I.: S5, Th
Mader, W.: P27, Th
Magon, S.: P37, F
Maguire, M.J.: P20, Th
Malaia, E.: P16, Th; P64, F
Manes, F.: P9, F
Marangolo, P.: P53, F
Marantz, A.: P63, Th; P64, Th
Mariani, S.: P27, F
Marinos, D.: P71, F
Marshall, R.S.: P98, F
Martin, R.C.: P25, F
Maruyama, T.: P96, F
May, J.: P19, Th

Mayberry, R.I.: P63, F
Mazuka, R.: P73, F
McCarthy, B.: P18, Th
McGettigan, C.: P26, F
McKee, J.: P81, F
McMahon, K.: P7, Th
McMillan, C.: P10, Th; P80, F; P93, F; P100, F
Medler, D.: P3, Th
Meister, I.G.: S3, F
Ménard, L.: P49, Th; P52, F
Mencl, W.E.: P78, Th
Menenti, L.: S5, F
Merrickel, J.: P21, F
Mesgarani, N.: P11, F
Mesulam, M.-M.: P94, F
Meteyard, L.: P72, Th
Meunier, F.: P4, F; P7, F
Miceli, G.: P37, F
Michel, C.M.: P42, F
Miller, B.L.: P97, Th
Miller, L.M.: P8, F
Minzer, B.M.: P98, F
Miozzo, M.: P38, F
Misra M.: P57, Th
Miyazaki, M.: P103, F
Mo, D.: P14, Th
Mohamed, F.: P29, Th
Molinario, N.: P73, Th
Molnar, M.: P49, Th
Monaghan, P.: S4, F
Monahan, P.: P3, F
Monittola, G.: P37, F
Moore, P.S.: P20, Th
Morand, S.: P42, F
Morton, J.: P35, F
Motes, M.A.: P20, Th
Mottonen, R.: P59, F
Mueller, H.M.: P30, Th
Mueller, J.L.: P39, Th
Müller, H.M.: P5, Th
Muragaki, Y.: P96, F

N

Naccache, L.: P83, Th
Nakamura, A.: P39, Th
Napoliello, E.: P80, Th
Nath, A.: P10, F
Nazir, T.: P50, F; S4, F
Negreira, A.: P100, F
Neville, H.: P56, Th; P59, Th; P78, F; P94, Th
Ngan, E.: P28, F
Nickels, L.: P47, Th
Nicol, T.: P34, Th
Nimmo-Smith, I.: P72, Th
Nishimura, Y.: P95, Th; P95, Th
Nonaka, C.: P102, F
Norris, D.: P30, F; P79, F
Norris, D.G.: P31, Th
Nsouli, R.: P79, Th

●

Oberman, L.: P99, F
 Obler, L.K.: P101, F:
 Obleser, J.: P26, F
 Ogar, J.: P106, F:
 Ogar, J.M.: P97, Th
 Ogawa, M.: P95, Th
 Oishi, H.: P73, F
 Ojemann, G.: P39, F
 Okada, M.: P95, Th
 Ono, K.: P39, Th
 Ortiz, S.: P54, Th
 Osann, K.: S4, Th
 Osterhout, L.: P93, Th
 Otsu, Y.: P95, Th

P

Paczynski, M.: P100, Th
 Padden, D.: P42, Th
 Pajtas, P.: P58, F
 Pakulak, E.: P78, F; P94, Th
 Pallier, C.: P88, Th
 Palti, D.: P87, Th
 Parris, B.: P81, F
 Parrish, T.B.: P33, F
 Pascual-Leone, A.: P58, F; P99, F
 Pasley, B.N.: P11, F:
 Patterson, K.: P52, F:
 Pauker, E.: P92, Th:
 Paulignan, Y.: P50, F; S4, F
 Peelle, J.: P72, Th; P93, F
 Peelle, J.E.: P8, Th; P32, Th
 Peleg, O.: P6, Th
 Pell, M.D.: P68, F
 Penn, R.: P81, F
 Perego, P.: P98, Th:
 Perret, C.: P46, F
 Peschke, C.: P40, F
 Petrides, M.: K1, Th
 Peyrin, C.: P75, Th:
 Pike, B.: P47, F; P68, F
 Pillon, A.: P66, F; P106, F
 Pirmoradi, M.: P29, F:
 Poeppel, D.: P1, F; P12, F
 Polka, L.: P49, Th:
 Proverbio, A.M.: P27, F
 Provinciali, L.: P53, F:
 Pugh, K.: P78, Th:
 Pulvermuller, F.: P77, F; P52, F; P16, F; P38, F
 Purcel, J.: P80, Th:
 Pylkannen, L.: P93, Th:
 Pylkkänen, L.: P89, Th; P9, Th

Q

Qi, Z.: P13, Th:
 Qiao, E.: P83, Th:

R

Rabagliati, H.: P89, Th:
 Raizada, R.: P46, Th:
 Raizada, R. D. S. : P18, F

Ralph, L.M.: P23, Th:
 Rapcsak, S.Z.: P71, Th:
 Rapcsak, S.: P95, F:
 Rapcsak, S.Z.: P82, Th; P97, F
 Rapp, B.: P70, Th:
 Rastle, K.: P57, F:
 Reggiani, F.: P37, F:
 Regis, J.: P13, F:
 Reiterer, S.: P55, Th:
 Renaweera, R.: P64, F:
 Renoult, L.: P86, F:
 Renvall, H.: S6, Th:
 Rhone, A.: P19, F:
 Rickheit, G.: P5, Th:
 Ridder, V.: P43, Th:
 Riecker, A.: P76, Th:
 Rieger, J.W.: P5, F
 Riès, S.: P36, F:
 Riley, J.: P19, F; P21, F
 Rivera-Gaxiola, M.: P54, Th:
 Robert, M.: P29, F:
 Robson, H.: P23, Th:
 Rodd, J.M.: P8, Th; P33, Th
 Rodriguez, M.: P54, Th:
 Rogalski, E.: P94, F:
 Rohrer, J.D.: P76, F:
 Romo, H.: P54, Th:
 Rose, S.: P7, Th:
 Rossor, M.N.: P76, F:
 Rota, G.: S2, Th; P55, Th
 Royle, P.: P77, Th
 Rüschemeyer, S.A.: P39, Th
 Ryant, N.: P10, Th; P80, F
 Rykhlevskaia, E.: P101, F

S

Saalasti, S.: P23, F; P24, F
 Sadato, N.: P39, Th
 Sage, K.: P23, Th
 Sakai, K.L.: P96, F
 Salmas, P.: P65, F
 Salmelin, R.: S6, Th
 Sams, M.: P23, F; P24, F
 Sanders, L.: P101, Th
 Sanders, L.D.: P61, Th
 Santi, A.: P90, Th
 Sapolsky, D.: P100, F
 Sarty, G.E.: P11, Th
 Sat., M.: P51, F
 Saur, D.: P27, Th; P40, F; S5, Th
 Savill, N.: P60, Th
 Saxe, R.: P58, F
 Schacht, A.: P69, F
 Scharinger, M.: P20, F; P21, F
 Schelter, B.: P27, Th
 Schlesewsky, M.: P69, Th; S6, F
 Schmitz, M.: P71, F
 Schnell, S.: P27, Th
 Schnider, A.: P42, F
 Schnyer, D.: P101, F
 Schroeder, C.: K2, Th
 Schulz, G.: P44, F

Schwartz, M.F.: P102, Th; P56, F; S1, F
 Scott, S.K.: P26, F
 Segaert, K.: S5, F
 Seidenberg, M.: P35, F
 Seidenberg, M.S.: P3, Th; P15, Th
 Seidenberg, S.: S2, F
 Shabani, Z.: P52, F
 Shahn, A.J.: P8, F
 Shamma, S.A.: P11, F
 Shankweiler, D.: P78, Th
 Sharma, H.: P32, F
 Shen, E.Y.: P101, Th
 Shetreet, E.: P87, Th
 Shtyrov, Y.: P16, F; P52, F; P77, F
 Shvartsman, M.: P15, F
 Simmonds, A.: P48, Th
 Simpson, M.: P40, Th
 Sitaram, R.: S2, Th
 Skipper, J.L.: P62, F
 Skoe, E.: P34, Th
 Slevc, L.R.: P25, F
 Small, S.L.: P49, F; P28, Th; P61, F
 Smith, K.: P88, F
 Snedeker, J.: P82, F
 Snider, S.F.: P103, F
 Sobo, J.: P60, F
 Solodkin, A.: P28, Th
 Solomyak, O.: P63, Th
 Sommer, W.: P69, F
 Sosnoff, J.J.: P22, Th
 Soto, M.: P53, Th
 Spence, M.A.: S4, Th
 Spinelli, L.: P42, F
 Spiro, A.: P101, F
 Staub, A.: P101, Th
 Stefanatos, G.A.: P29, Th
 Steinbrink, C.: P76, Th
 Steinhauer, K.: P49, Th; P51, Th; P77, Th; P92, Th
 Stengel, B.C.: S2, F
 Stock, P.S.: P50, Th
 Su, I.F.: P68, Th
 Sugisaki, K.: P95, Th
 Sugiura, G.: P39, Th
 Swank, P.: P88, F
 Sysoeva, O.: P66, Th
 Szenkovits, G.: P30, F
 Szwed, M.: P67, Th; P83, Th

T

Tabor, W.: P78, Th
 Tainturier, M.J.: P74, Th
 Takeichi, H.: P25, Th
 Takeuchi, F.: P25, Th
 Talavage, T.: P64, F
 Tam, J.W.: P57, Th
 Tamminen, J.: P40, Th
 Tanaka, Y.: P103, F
 Tebaldi, F.: P53, F
 Terao, A.: P25, Th
 Teubner-Rhodes, S.: P12, F

Theodoridou, A.: P92, F
Thierry, G.: P74, Th; P60, Th
Thompson-Schill, S.: P87, F; P102, Th
Thompson, C.K.: P33, F; P55, F
Thornton, R.: P47, Th
Thothathiri, M.: P102, Th
Tiippana, K.: P23, F; P24, F
Toni, I.: P67, F
Towle, V.L.: P81, F
Townsend, J.: P35, Th:
Trebuchon-Da Fonseca, A.: P13, F
Tremblay, P.: P47, F; P48, F; P49, F
Troiani, V.: P32, Th; P93, F
Trujillo, N.: P24, Th:
Tsao, F.M.: P18, F:
Turken, A.: P106, F:

U

Umeda, S.: P95, Th:

V

Valabrègue, R.: P67, Th; P83, Th
Valdois, S.: P74, Th; P75, Th
Vannuscorps, G.: P66, F:
Vartiainen, J.: S6, Th:
Veit, R.: S2, Th:
Vesely, L.: P100, F:
Vinckier, F.: P83, Th:
Virtue, S.: P18, Th

Vohn, R.: P83, F; P92, F
von Wendt, L.: P23, F; P24, F

W

Walker, G.: S1, F
Wang, S.: P14, Th
Wang, Y.: P50, Th
Warren, J.D.: P17, F; P76, F
Warren, J.E.: P17, F; P76, F
Wartenburger, I.: P58, Th
Watkins, K.: K3, F
Watkins, K.E.: P59, F
Wayland, R.: P14, F
Weber-Fox, C.: P16, Th
Weekes, B.S.: P68, Th
Weiller, C.: S5, Th; P27, Th; P31, F; P40, F
Weintraub, S.: P94, F
Weiss, S.: P5, Th; P30, Th
Welcome, S.: P65, Th
Werker, J.: P38, Th
Wicha, N.: P54, Th
Wieneke, C.: P94, F
Wilbur, R.B.: P16, Th; P64, F
Wilkins, D.: P106, F
Willems, R.M.: P67, F
Wilson, S.: P89, F
Wilson, S.M.: P97, Th
Wise, R.J.S.: P48, Th; P17, F; P62, Th
Wolfson, J.: P40, Th
Wong, P.: P41, Th

Wong, P.C.M: P74, F
Woodbury, R.: P84, F
Woodhead, Z.V.J.: P62, Th
Wu, A.D.: S3, F

Y

Xiang, H.D.: P31, Th

Y

Yamada, Y.: P56, Th; P78, F
Yamamoto, T.: P95, Th
Yang, F.: P2, Th
Yang, F.J.: P37, F
Yokoyama, E.: P103, F
Yoshida, E.: P95, Th
Yuen, I.: P57, F

Z

Zahn, R.: P23, Th
Zaidel, E.: P17, Th
Zani, A.: P27, F
Zevin, D.: P62, F
Ziegler, W.: P40, F
Zimmerman, M.: P43, Th
Zinchenko, E.: P82, F
Zwitterslood, P.: S1, Th; P43, Th

