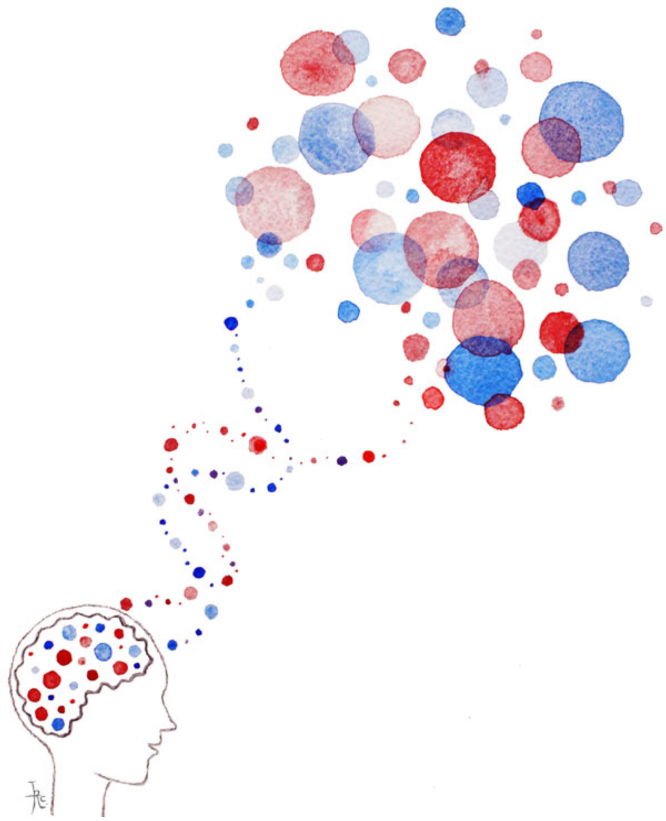
The Bilingual Brain



LSA Summer Institute 2019
Class 341
Tuesdays and Fridays: 1:05-2:30

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Office Hours by Appointment

Course Description

This class provides exposure to the current topics in study of the brain and bilingualism. The course will introduce attendees with a variety of backgrounds to the rapidly growing field of neurolinguistics, with a special focus on bilingualism. Although the study of language deficits in people with brain damage or degenerative neural diseases has been around for a long time, neuroimaging methods, such as magnetic resonance imaging and electrophysiology, have been applied more recently to questions about the way that language is processed in the brain. Bilingualism provides a unique lens for understanding fundamental concepts about language processing, such as the interactions between different levels of language representation, what drives language change, and individual differences in language processing.

After an introduction to regions of the brain traditionally thought to be involved in language processing, we turn to topics of interest in the field today. Students will learn about the similarities and differences seen for processing in the native versus a non-native language. They will explore recent research on neuroplasticity in adulthood and how it relates to the debate on critical periods and develop an understanding of the "bilingual cognitive advantage" debate and its relation to the notion of cognitive reserve. Students will obtain a foundational understanding of neurolinguistic methods, which will allow them to further explore research in this area beyond the course.

Course Schedule

Class 1: June 25
Introduction Class structure and expectations
Introduction to Neurolinguistics for our purposes: brain regions and networks implicated in language and techniques for studying them
Who you are, the Qs you bring to class
Intro to Piazza
Definition of terms: bilingualism, multilingualism, plasticity, cognitive effects on language

Class 2: June 28
Quiz on brain regions
Topic: Neurolinguistic methods and multilingual aphasia

Class 3: July 2
Topic: Cognition

Class 4: July 5
Topic: Lexical-semantics in bilingualism

Class 5: July 9
Topic: Second-language Learning, individual differences in L2 learning and mastery (talent, aphasia)

Class 6: July 12
Topic: Cross-linguistic influence, syntactic processing, code-switching

Class 7: July 16
Topic: Language Attrition in neurotypicals and others

Class 8: July 19
Topic: Aging, Alzheimer's disease, wrap-up and responses to lingering Qs

Class Requirements

Students are expected to come to class prepared for the discussion (having completed one of the assigned readings BEFORE the class) and to actively participate in class discussions. After completing the reading, you will be expected to post your thoughts on it on Piazza by 6:00 pm the day before each class. The comment should be about a paragraph long. It can include what you found most interesting about the reading, what you agreed or disagreed with and why, how it relates to your own experiences, how it relates to other readings you've done for this class or elsewhere, whether it prompted you to wonder about something, etc.

Students are expected to attend each class. In the unfortunate instance that you must miss a class, read a second article on the topic of the class, post a second article response on the second article you read, and post comments on someone else's article response.

Piazza

We will use Piazza for this course. On this site, you will be able to see class announcements, download PDFs of the class readings, submit reading reflections, ask questions to other students or the instructors, and submit extra-credit multilingualism examples. You are welcome to share other articles or content related to the class topics, both academic and non-academic, and pose thought-provoking questions that you'd like to engage others in discussion about. We hope this will stimulate discussion and interest in different ways of thinking about brain processing and multilingualism.

Find our class site at: piazza.com/lsa_linguistic_institute/summer2019/li341
Access code: bilingual-brain

Assessments

Any student who completes the class requirements gets at least a B. Anyone who contributes particularly thoughtful comments or questions on the papers we read, either in class or on Piazza, may be graded higher.

We encourage you to submit examples that you encounter of multilingualism throughout the course on Piazza. Up to 5 submissions will be counted as extra credit added to your final grade. Examples of submissions can include stories of things that you witness or experience in everyday life, articles in the popular press, blog entries on what it means to be multilingual or multicultural in the U.S., videos, interviews, documentaries, comics, etc. No articles from academic journals for this assignment. If you're including a link to the source, please write a few sentences about what you think about it or why you think other people in the class would find it interesting. It must use English as its base text (it's ok if a certain amount is in another language, but preferably this is explained in English) so that the whole class can appreciate it. You are welcome to post more than five if you want. Use the tag "multilingualism_examples" when posting these.

Laptops, tablets, and phones

Use of laptops and tablets in class is permitted for note-taking and viewing course-related materials. During class, the wireless connection must be turned off and all sounds must be muted. Checking email, Facebook (or any other social networking site), and using chat is prohibited during class. If these restrictions are not met, the student will not be permitted to use the device during the class period. If another student is using a laptop in class in a way that is distracting to you, please let us know.

Did you know that researchers have found that students who use laptops for note-taking during class retain LESS content in memory than those who hand-write their notes? Read more about it in some articles Eve posted on Piazza:

- A research paper by Sana, Weston, & Cepeda (2013), "Laptop multitasking hinders classroom learning for both users and nearby peers"
- A Washington Post article by Michael Rosenwald on online vs. book reading, "Serious reading takes a hit from online scanning and skimming, researchers say"

- An insightful introspective account by Michael Harris of his loss of focused attention abilities in "'War and Peace' tortured me: Facebook, email and the neuroscience of always being distracted"

Accommodations

If you need any accommodations to best benefit from this class, let us know by June 28.

Quiz on brain regions

Label and draw

- Neuron, cell body, axon, dendrite, synapse
- Cortex = grey matter, white matter
- Lobes: Frontal, temporal, parietal, occipital
- Rolandic fissure = central fissure
- Sylvian fissure
- Broca's area, Wernicke's area
- Arcuate fasciculus
- Corpus callosum
- Insula
- Medial view
- Cingulate Cortex
- Subcortical structures (hypothalamus, caudate body)
- Directions (anterior, posterior, ventral, dorsal, superior, inferior, caudal, rostral, lateral and medial, mid-sagittal, sagittal, axial, coronal)

Recommended resources for learning about brain regions

Google images
http://images.google.com

FINR Brain Atlas
http://www.finr.net/educational-resources/finr-educational-materials/3d-brain/

Brain Voyager Brain Tutor
http://www.brainvoyager.com/BrainTutor.html

Anatomie Amsterdam
http://www.anatomie-amsterdam.nl/sub_sites/anatomie-zenuwwerking/123_neuro/start.htm

Allen Human Brain Atlas – Brain Explorer® 2
http://human.brain-map.org/static/brainexplorer

Brodmann's Interactive Atlas
http://www.fmriconsulting.com/brodmann/Interact.html

Readings

For each topic, we have chosen 3 articles to represent just a few of the exciting areas of research within that topic. The requirement is to read just one of these and comment on it on Piazza. However, the chosen readings represent different perspectives or different aspects of language processing or bilingual experience, so you may want to read more than one, if you have time and interest in doing so, in order to gain a more complete perspective of the literature on the brain and language on that particular topic.

Class 1: June 25

Overview – recommended before course or during week 1
No Piazza post is required for these readings.

Higby, E., Kim, J., & Obler, L. K. (2013). Multilingualism and the brain. *Annual Review of Applied Linguistics*, *33*, 68–101. http://doi.org/10.1017/S0267190513000081

Over the last decade, research on multilingualism has grown and has provided researchers with new insights into the mechanisms at work in the multilingual brain. While some studies of multilinguals have shown similar results to what has been seen in studies of bilinguals, certain unique properties of multilinguals are beginning to be noticed, particularly regarding early language representation, gray matter density, and speed of lexical retrieval. In addition, research on cognitive control, language switching, working memory, and certain consequences of multilingualism (advantages and disadvantages) are re- viewed in terms of their effects on the brains of bilinguals and multilinguals. Although there is little agreement among papers concerning specific regions that are structurally different in monolinguals and multilinguals, publications do show differences. Similarly, there are studies reporting somewhat different regions called upon for processing a given language in multilinguals compared to monolinguals.

Kovelman, I. (2016). Neuroimaging methods. In E. Hoff (Ed.), *Research methods in child language: A practical guide* (1st ed., pp. 1–17). Blackwell Publishing.

One of the most pervasive questions in the field of language acquisition is, "How does the human brain acquire language?" Noninvasive neuroimaging technologies and the emerging field of developmental cognitive neuroscience now offer both the technology and the growing expertise to examine the neural correlates of language acquisition. In this chapter we review the basic principles of electric (ERP, MEG) and hemodynamic (fMRI, fNIRS) neuroimaging technologies and how they can be used to study children. We also discuss how these neuroimaging methods have now been successfully applied to the study of language acquisition in typically developing children as well as in children with language learning impairments and dyslexia.

Class 2: June 28

Topic: Neurolinguistic methods and multilingual aphasia

Pitres, A. (1895) Etude sur l'aphasie chez les polyglottes.

In this study, neurologist Pitres describes 9 cases of aphasia (the breakdown of language resulting from brain injury) in multilinguals. He posits that it is the language most used around the time of the injury that is most likely to return (although in fact, for most individuals, the languages are impaired in proportion to individuals' proficiency before the injury).

Kim, K. H., Relkin, N. R., Lee, K. M., & Hirsch, J. (1997). Distinct cortical areas associated with native and second languages. *Nature, 388*(6638), 171-174.

The ability to acquire and use several languages selectively is a unique and essential human capacity. Here we investigate the fundamental question of how multiple languages are represented in a human brain. We applied functional magnetic resonance imaging (fMRI) to determine the spatial relationship between native and second languages in the human cortex, and show that within the frontal-lobe language-sensitive regions (Broca's area), second languages acquired in adulthood ('late' bilingual subjects) are spatially separated from native languages. However, when acquired during the early language acquisition stage of development ('early' bilingual subjects), native and second languages tend to be represented in common frontal cortical areas. In both late and early bilingual subjects, the temporal-lobe language- sensitive regions (Wernicke's area) also show effectively little or no separation of activity based on the age of language acquisition. This discovery of language-specific regions in Broca's area advances our understanding of the cortical representation that underlies multiple language functions.

Kuhl, P. K., Stevenson, J., Corrigan, N. M., van den Bosch, J. J., Can, D. D., & Richards, T. (2016). Neuroimaging of the bilingual brain: Structural brain correlates of listening and speaking in a second language. *Brain and Language*, *162*, 1-9.

Diffusion tensor imaging was used to compare white matter structure between American monolingual and Spanish-English bilingual adults living in the United States. In the bilingual group, relationships between white matter structure and naturalistic immersive experience in listening to and speaking English were additionally explored. White matter structural differences between groups were found to be bilateral and widespread. In the bilingual group, experience in listening to English was more robustly correlated with decreases in radial and mean diffusivity in anterior white matter regions of the left hemi- sphere, whereas experience in speaking English was more robustly correlated with increases in fractional anisotropy in more posterior left hemisphere white matter regions. The findings suggest that (a) foreign language immersion induces neuroplasticity in the adult brain, (b) the degree of alteration is proportional to language experience, and (c) the modes of immersive language experience have more robust effects on different brain regions and on different structural features.

Class 3: July 2

Topic: Cognition

Bialystok, E., Craik, F. I. M., & Luk, G. (2012). Bilingualism: consequences for mind and brain. *Trends in Cognitive Sciences*, *16*(4), 240–250. http://doi.org/10.1016/j.tics.2012.03.001

Building on earlier evidence showing a beneficial effect of bilingualism on children's cognitive development, we review recent studies using both behavioral and neuro- imaging methods to examine the effects of bilingualism on cognition in adulthood and explore possible mechanisms for these effects. This research shows that bilingualism has a somewhat muted effect in adulthood but a larger role in older age, protecting against cognitive decline, a concept known as 'cognitive reserve'. We discuss recent evidence that bilingualism is associated with a delay in the onset of symptoms of dementia. Cognitive reserve is a crucial research area in the context of an aging population; the possibility that bilingualism contributes to cognitive reserve is therefore of growing importance as populations become increasingly diverse.

Li, L., Abutalebi, J., Zou, L., Yan, X., Liu, L., Feng, X., et al. (2015). Bilingualism alters brain functional connectivity between "control" regions and 'language' regions: Evidence from bimodal bilinguals. *Neuropsychologia. 71,* 236-247. http://doi.org/10.1016/j.neuropsychologia.2015.04.007

Previous neuroimaging studies have revealed that bilingualism induces both structural and functional neuroplasticity in the dorsal anterior cingulate cortex (dACC) and the left caudate nucleus (LCN), both of which are associated with cognitive control. Since these "control" regions should work together with other language regions during language processing, we hypothesized that bilingualism may also alter the functional interaction between the dACC/LCN and language regions. Here we tested this hypothesis by exploring the functional connectivity (FC) in bimodal bilinguals and monolinguals using functional MRI when they either performed a picture naming task with spoken language or were in resting state. We found that for bimodal bilinguals who use spoken and sign languages, the FC of the dACC with regions involved in spoken language (e.g. the left superior temporal gyrus) was stronger in performing the task, but weaker in the resting state as compared to monolinguals. For the LCN, its intrinsic FC with sign language regions including the left inferior temporo-occipital part and right inferior and superior parietal lobules was increased in the bilinguals. These results demonstrate that bilingual experience may alter the brain functional interaction between "control" regions and "language" regions. For different control regions, the FC alters in different ways. The findings also deepen our understanding of the functional roles of the dACC and LCN in language processing.

Abutalebi, J., & Green, D. W. (2016). Neuroimaging of language control in bilinguals: Neural adaptation and reserve. *Bilingualism: Language and Cognition, 19*(4), 689–698. http://doi.org/10.1017/S1366728916000225

Speaking more than one language demands a language control system that allows bilinguals to correctly use the intended language adjusting for possible interference from the non-target language. Understanding how the brain orchestrates the control of language has been a major focus of neuroimaging research on bilingualism and was central to our original neurocognitive language control model (Abutalebi & Green, 2007). We updated the network of language control (Green & Abutalebi, 2013) and here review the many new exciting findings based on functional and structural data that substantiate its core components. We discuss the language control network within the framework of the adaptive control hypothesis (Green & Abutalebi, 2013) that predicts adaptive changes specific to the control demands of the interactional contexts of language use. Adapting to such demands leads, we propose, to a neural reserve in the human brain.

Class 4: July 5

Topic: Lexical-semantics in bilingualism

Thierry, G., & Wu, Y. J. (2007). Brain potentials reveal unconscious translation during foreign-language comprehension. *Proceedings of the National Academy of Sciences*, 1–6.

Whether the native language of bilingual individuals is active during second-language comprehension is the subject of lively debate. Studies of bilingualism have often used a mix of first- and second-language words, thereby creating an artificial "dual-language" context. Here, using event-related brain potentials, we demonstrate implicit access to the first language when bilinguals read words exclusively in their second language. Chinese–English bilinguals were required to decide whether English words presented in pairs were related in meaning or not; they were unaware of the fact that half of the words concealed a character repetition when translated into Chinese. Whereas the hidden factor failed to affect behavioral performance, it significantly modulated brain potentials in the expected direction, establishing that English words were automatically and unconsciously translated into Chinese. Critically, the same modulation was found in Chinese monolinguals reading the same words in Chinese, i.e., when Chinese character repetition was evident. Finally, we replicated this pattern of results in the auditory modality by using a listening comprehension task. These findings demonstrate that native-language activation is an unconscious correlate of second-language comprehension.

Grogan, A., Parker Jones, O., Ali, N., Crinion, J., Orabona, S., Mechias, M. L., ...Price, C. J. (2012). Structural correlates for lexical efficiency and number of languages in non-native speakers of English. *Neuropsychologia, 50*(7), 1347-1352.

We used structural magnetic resonance imaging (MRI) and voxel based morphometry (VBM) to investigate whether the efficiency of word processing in the non-native language (lexical efficiency) and the number of non-native languages spoken (2+ versus 1) were related to local differences in the brain structure of bilingual and multilingual speakers. We dissociate two different correlates for non-native language processing. Firstly, multilinguals who spoke 2 or more non-native languages had higher grey matter density in the right posterior supramarginal gyrus compared to bilinguals who only spoke one non-native language. This is interpreted in relation to previous studies that have shown that grey matter density in this region is related to the number of words learnt in bilinguals relative to monolinguals and in monolingual adolescents with high versus low vocabulary. Our second result was that, in bilinguals, grey matter density in the left pars opercularis was positively related to lexical efficiency in second language use, as measured by the speed and accuracy of lexical decisions and the number of words produced in a timed verbal fluency task. Grey matter in the same region was also negatively related to the age at which the second language was acquired. This is interpreted in terms of previous findings that associated the left pars opercularis with phonetic expertise in the native language.

Strijkers, K., Costa, A., & Thierry, G. (2010). Tracking lexical access in speech production: Electrophysiological correlates of word frequency and cognate effects. *Cerebral Cortex*, *20*(4), 912–928.
http://doi.org/10.1093/cercor/bhp153

The present study establishes an electrophysiological index of lexical access in speech production by exploring the locus of the frequency and cognate effects during overt naming. We conducted 2 event-related potential (ERP) studies with 16 Spanish--Catalan bilinguals performing a picture naming task in Spanish (L1) and 16 Catalan--Spanish bilinguals performing a picture naming task in Spanish (L2). Behavioral results showed a clear frequency effect and an interaction between frequency and cognate status. The ERP elicited during the production of high-frequency words diverged from the low-frequency ERP between 150 and 200 ms post-target presentation and kept diverging until voice onset. The same results were obtained when comparing cognate and noncognate conditions. Positive correlations were observed between naming latencies and mean amplitude of the P2 component following the divergence, for both the lexical frequency and the cognate effects. We conclude that lexical access during picture naming begins approximately 180 ms after picture presentation. Furthermore, these results offer direct electrophysiological evidence for an early influence of frequency and cognate status in speech production. The theoretical implications of these findings for models of speech production are discussed.

Class 5: July 9

Topic: Second-language learning, individual differences in L2 learning and mastery (talent, aphasia)

Stein, M., Federspiel, A., Koenig, T., Wirth, M., Strik, W., Wiest, R., ... Dierks, T. (2012). Structural plasticity in the language system related to increased second language proficiency. *Cortex, 48*(4), 458-465.

While functional changes linked to second language learning have been subject to extensive investigation, the issue of learning-dependent structural plasticity in the fields of bilingualism and language comprehension has so far received less notice. In the present study we used voxel-based morphometry to monitor structural changes occurring within five months of second language learning. Native English-speaking exchange students learning German in Switzerland were examined once at the beginning of their stay and once about five months later, when their German language skills had significantly increased. We show that structural changes in the left inferior frontal gyrus are correlated with the increase in second language proficiency as measured by a paper-and-pencil language test. Contrary to the increase in proficiency and grey matter, the absolute values of grey matter density and second language proficiency did not correlate (neither on first nor on second measurement). This indicates that the individual amount of learning is reflected in brain structure changes, regardless of absolute proficiency.

Tanner, D., McLaughlin, J., Herschensohn, J., & Osterhout, L. (2013). Individual differences reveal stages of L2 grammatical acquisition: ERP evidence. *Bilingualism: Language and Cognition, 16*(2), 367-382.

Here we report findings from a cross-sectional study of morphosyntactic processing in native German speakers and native English speakers enrolled in college-level German courses. Event-related brain potentials were recorded while participants read sentences that were either well-formed or violated German subject–verb agreement. Results showed that grammatical violations elicited large P600 effects in the native Germans and learners enrolled in third-year courses. Grand mean waveforms for learners enrolled in first-year courses showed a biphasic N400–P600 response. However, subsequent correlation analyses revealed that most individuals showed either an N400 or a P600, but not both, and that brain response type was associated with behavioral measures of grammatical sensitivity. These results support models of second language acquisition which implicate qualitative changes in the neural substrates of second language grammar processing associated with learning. Importantly, we show that new insights into L2 learning result when the cross-subject variability is treated as a source of evidence rather than a source of noise.

Weber, K., Christiansen, M. H., Petersson, K. M., Indefrey, P., & Hagoort, P. (2016). fMRI syntactic and lexical repetition effects reveal the initial stages of learning a new language. *Journal of Neuroscience*, *36*(26), 6872–6880. http://doi.org/10.1523/JNEUROSCI.3180-15.2016

When learning a new language, we build brain networks to process and represent the acquired words and syntax and integrate these with existing language representations. It is an open question whether the same or different neural mechanisms are involved in learning and processing a novel language compared with the native language(s). Here we investigated the neural repetition effects of repeating known and novel word orders while human subjects were in the early stages of learning a new language. Combining a miniature language with a syntactic priming paradigm, we examined the neural correlates of language learning on-line using functional magnetic resonance imaging. In left inferior frontal gyrus and posterior temporal cortex, the repetition of novel syntactic structures led to repetition enhancement, whereas repetition of known structures resulted in repetition suppression. Additional verb repetition led to an increase in the syntactic repetition enhancement effect in language-related brain regions. Similarly, the repetition of verbs led to repetition enhancement effects in areas related to lexical and semantic processing, an effect that continued to increase in a subset of these regions. Repetition enhancement might reflect a mechanism to build and strengthen a neural network to process novel syntactic structures and lexical items. By contrast, the observed repetition suppression points to overlapping neural mechanisms for native and new language constructions when these have sufficient structural similarities.

Class 6: July 12

Topic: Cross-linguistic influence, syntactic processing, code-switching

Peltola, M. S., Tamminen, H., Toivonen, H., Kujala, T., & Naatanen, R. (2012). Different kinds of bilinguals - Different kinds of brains: The neural organisation of two languages in one brain. *Brain and Language; Brain and Language*, *121*(3), 261–266. http://doi.org/10.1016/j.bandl.2012.03.007

The aim of this study was to determine whether the type of bilingualism affects neural organisation. We performed identification experiments and mismatch negativity (MMN) registrations in Finnish and Swedish language settings to see, whether behavioural identification and neurophysiological discrimination of vowels depend on the linguistic context, and whether there is a difference between two kinds of bilinguals. The stimuli were two vowels, which differentiate meaning in Finnish, but not in Swedish. The results indicate that Balanced Bilinguals are inconsistent in identification performance, and they have a longer MMN latency. Moreover, their MMN amplitude is context-independent, while Dominant Bilinguals show a larger MMN in the Finnish context. These results indicate that Dominant Bilinguals inhibit the preattentive discrimination of native contrast in a context where the distinction is non-phonemic, but this is not possible for Balanced Bilinguals. This implies that Dominant Bilinguals have separate systems, while Balanced Bilinguals have one inseparable system.

Kovelman, I., Baker, S.A., & Petitto, L. A. (2008). Bilingual and monolingual brains compared : a functional magnetic resonance imaging investigation of syntactic processing and a possible « neural signature » of bilingualism. *Journal of Cognitive Neuroscience, 20*(1), 153-169.

Does the brain of a bilingual process language differently from that of a monolingual? We compared how bilinguals and monolinguals recruit classic language brain areas in response to a language task and asked whether there is a "neural signature" of bilingualism. Highly proficient and early-exposed adult Spanish–English bilinguals and English monolinguals participated. During functional magnetic resonance imaging (fMRI), participants completed a syntactic "sentence judgment task" [Caplan, D., Alpert, N., & Waters, G. Effects of syntactic structure and propositional number on patterns of regional cerebral blood flow. Journal of Cognitive Neuroscience, 10, 541–552, 1998]. The sentences exploited differences between Spanish and English linguistic properties, allowing us to explore similarities and differences in behavioral and neural responses between bilinguals and monolinguals, and between a bilingual's two languages. If bilinguals' neural processing differs across their two languages, then differential behavioral and neural patterns should be observed in Spanish and English. Results show that behaviorally, in English, bilinguals and monolinguals had the same speed and accuracy, yet, as predicted from the Spanish–English structural differences, bilinguals had a different pattern of performance in Spanish. fMRI analyses revealed that both monolinguals (in one language) and bilinguals (in each language) showed predicted increases in activation in classic language areas (e.g., left inferior frontal cortex, LIFC), with any neural differences between the bilingual's two languages being principled and predictable based on the morphosyntactic differences between Spanish and English. However, an important difference was that bilinguals had a significantly greater increase in the blood oxygenation level-dependent signal in the LIFC (BA 45) when processing English than the English monolinguals. The results provide insight into the decades-old question about the degree of separation of bilinguals' dual-language representation. The differential activation for bilinguals and monolinguals opens the question as to whether there may possibly be a "neural signature" of bilingualism. Differential activation may further provide a fascinating window into the language processing potential not recruited in monolingual brains and reveal the biological extent of the neural architecture underlying all human language.

Beatty-Martinez, A. L., & Dussias, P. E. (2017). Bilingual experience shapes language processing: Evidence from codeswitching. *Journal of Memory and Language*, *95*, 173–189. http://doi.org/10.1016/j.jml.2017.04.002

We report three experiments on two groups of Spanish–English bilinguals who differed in codeswitching experience (codeswitchers and non-codeswitchers) to examine how different production choices predict comprehension difficulty. Experiment 1 examined the processing of gender congruent and gender incongruent determiner-noun switches in sentential contexts using event-related potentials. While codeswitchers demonstrated N400 sensitivity to congruency manipulations, non-codeswitchers showed a modulation of early frontal EEG activity to switching, regardless of switch type. Experiment 2 validated the translation-equivalent target words compared in Experiment 1. In Experiment 3, the bilinguals who participated in Experiment 1 completed a task that elicited naturally-produced codeswitched speech. Codeswitchers switched more often than non-codeswitchers, and their switches robustly reflected the conditions that were more easily processed in Experiment 1. Together, the results indicate the comprehension system becomes optimally attuned to variation in the input, and demonstrate that switching costs depend on the type of codeswitch and bilinguals' language experience.

Class 7: July 16

Topic: Language Attrition in neurotypicals and others

Pallier, C., Dehaene, S., Poline, J.-B., LeBihan, D., Argenti, A. M., Dupoux, E., & Mehler, J. (2003). Brain imaging of language plasticity in adopted adults: Can a second language replace the first? *Cerebral Cortex*, *13*(2), 155–161.

Do the neural circuits that subserve language acquisition lose plasticity as they become tuned to the maternal language? We tested adult subjects born in Korea and adopted by French families in childhood; they have become fluent in their second language and report no conscious recollection of their native language. In behavioral tests assessing their memory for Korean, we found that they do not perform better than a control group of native French subjects who have never been exposed to Korean. We also used event-related functional magnetic resonance imaging to monitor cortical activations while the Korean adoptees and native French listened to sentences spoken in Korean, French and other, unknown, foreign languages. The adopted subjects did not show any specific activations to Korean stimuli relative to unknown languages. The areas activated more by French stimuli than by foreign stimuli were similar in the Korean adoptees and in the French native subjects, but with relatively larger extents of activation in the latter group. We discuss these data in light of the critical period hypothesis for language acquisition.

Kasparian, K., & Steinhauer, K. (2017). When the second language takes the lead: Neurocognitive processing changes in the first language of adult attriters. *Frontiers in Psychology*, *8*(389), 1-22.
http://doi.org/10.1177/003435520104400407

Although research on multilingualism has revealed continued neuroplasticity for language-learning beyond what was previously expected, it remains controversial whether and to what extent a second language (L2) acquired in adulthood may induce changes in the neurocognitive processing of a first language (L1). First language (L1) attrition in adulthood offers new insight on neuroplasticity and the factors that modulate neurocognitive responses to language. To date, investigations of the neurocognitive correlates of L1 attrition and of factors influencing these mechanisms are still scarce. Moreover, most event-related-potential (ERP) studies of second language processing have focused on L1 influence on the L2, while cross-linguistic influence in the reverse direction has been underexplored. Using ERPs, we examined the real-time processing of Italian relative-clauses in 24 Italian-English adult migrants with predominant use of English since immigration and reporting attrition of their native-Italian (Attriters), compared to 30 non-attriting monolinguals in Italy (Controls). Our results showed that Attriters differed from Controls in their acceptability judgment ratings and ERP responses when relative clause constructions were ungrammatical in English, though grammatical in Italian. Controls' ERP responses to unpreferred sentence constructions were consistent with garden path effects typically observed in the literature for these complex sentences. In contrast, due to L2-English influence, Attriters were less sensitive to semantic cues than to word-order preferences, and processed permissible Italian sentences as outright morphosyntactic violations. Key factors modulating processing differences within Attriters were the degree of maintained L1 exposure, length of residence in the L2 environment and L2 proficiency – with higher levels of L2 immersion and proficiency associated with increased L2 influence on the L1. To our knowledge, this is the first demonstration that high levels of L2 proficiency and exposure may render a grammatical sentence in one's native language ungrammatical. These group differences strongly point to distinct processing strategies and provide evidence that even a "stabilized" L1 grammar is subject to change after a prolonged period of L2 immersion and reduced L1 use, especially in linguistic areas promoting cross-linguistic influence.

Bergmann, C., Meulman, N., Stowe, L. A., Sprenger, S. A., & Schmid, M. S. (2015). Prolonged L2 immersion engenders little change in morphosyntactic processing of bilingual natives. *Neuroreport*, *26*(17), 1065–1070. http://doi.org/10.1097/WNR.0000000000000469

Bilingual and monolingual language processing differ, presumably because of constant parallel activation of both languages in bilinguals. We attempt to isolate the effects of parallel activation in a group of German first-language (L1) attriters, who have grown up as monolingual natives before emigrating to an L2 environment. We hypothesized that prolonged immersion will lead to changes in the processing of morphosyntactic violations. Two types of constructions were presented as stimuli in an event-related potential experiment: (1) verb form combinations (auxiliaries + past participles and modals + infinitives) and (2) determiner–noun combinations marked for grammatical gender. L1 attriters showed the same response to violations of gender agreement as monolingual controls (i.e. a significant P600 effect strongest over posterior electrodes). Incorrect verb form combinations also elicited a significant posterior P600 effect in both groups. In attriters, however, there was an additional posterior N400 effect for this type of violation. Such biphasic patterns have been found before in L1 and L2 speakers of English and might reflect the influence of this language. Generally, we interpret our results as evidence for the stability of the deeply entrenched L1 system, even in the face of L2 interference.

Class 8: July 19

Topic: Aging, Alzheimer's disease, wrap-up and responses to lingering Qs

Gold, B. T., Johnson, N. F., & Powell, D. K. (2013). Lifelong bilingualism contributes to cognitive reserve against white matter integrity declines in aging. *Neuropsychologia*, *51*(13), 2841–2846. http://doi.org/10.1016/j.neuropsychologia.2013.09.037

Recent evidence suggests that lifelong bilingualism may contribute to cognitive reserve (CR) in normal aging. However, there is currently no neuroimaging evidence to suggest that lifelong bilinguals can retain normal cognitive functioning in the face of age-related neurodegeneration. Here we explored this issue by comparing white matter (WM) integrity and gray matter (GM) volumetric patterns of older adult lifelong bilinguals (N¼20) and monolinguals (N¼20). The groups were matched on a range of relevant cognitive test scores and on the established CR variables of education, socioeconomic status and intelligence. Participants underwent high-resolution structural imaging for assessment of GM volume and diffusion tensor imaging (DTI) for assessment of WM integrity. Results indicated significantly lower microstructural integrity in the bilingual group in several WM tracts. In particular, compared to their monolingual peers, the bilingual group showed lower fractional anisotropy and/or higher radial diffusivity in the inferior longitudinal fasciculus/inferior fronto-occipital fasciculus bilaterally, the fornix, and multiple portions of the corpus callosum. There were no group differences in GM volume. Our results suggest that lifelong bilingualism contributes to CR against WM integrity declines in aging.

Alladi, S., Bak, T. H., Duggirala, V., Surampudi, B., Shailaja, M., Shukla, A. K., et al. (2013). Bilingualism delays age at onset of dementia, independent of education and immigration status. *American Academy of Neurology*, 1–7.

Objectives: The purpose of the study was to determine the association between bilingualism and age at onset of dementia and its subtypes, taking into account potential confounding factors.

Methods: Case records of 648 patients with dementia (391 of them bilingual) diagnosed in a specialist clinic were reviewed. The age at onset of first symptoms was compared between monolingual and bilingual groups. The influence of number of languages spoken, education, occupation, and other potentially interacting variables was examined.

Results: Overall, bilingual patients developed dementia 4.5 years later than the monolingual ones. A significant difference in age at onset was found across Alzheimer disease dementia as well as frontotemporal dementia and vascular dementia, and was also observed in illiterate patients. There was no additional benefit to speaking more than 2 languages. The bilingual effect on age at dementia onset was shown independently of other potential confounding factors such as education, sex, occupation, and urban vs rural dwelling of subjects.

Conclusions: This is the largest study so far documenting a delayed onset of dementia in bilingual patients and the first one to show it separately in different dementia subtypes. It is the first study reporting a bilingual advantage in those who are illiterate, suggesting that education is not a sufficient explanation for the observed difference. The findings are interpreted in the context of the bilingual advantages in attention and executive functions.

Schweizer, T. A., Ware, J., Fischer, C. E., Craik, F. I. M., & Bialystok, E. (2012). Bilingualism as a contributor to cognitive reserve: Evidence from brain atrophy in Alzheimer's disease. *Cortex*, *48*(8), 991–996. http://doi.org/10.1016/j.cortex.2011.04.009

Much of the research on delaying the onset of symptoms of Alzheimer's disease (AD) has focused on pharmacotherapy, but environmental factors have also been acknowledged to play a significant role. Bilingualism may be one factor contributing to 'cognitive reserve' (CR) and therefore to a delay in symptom onset. If bilingualism is protective, then the brains of bilinguals should show greater atrophy in relevant areas, since their enhanced CR enables them to function at a higher level than would be predicted from their level of disease. We analyzed a number of linear measurements of brain atrophy from the computed tomography (CT) scans of monolingual and bilingual patients diagnosed with probable AD who were matched on level of cognitive performance and years of education. Bilingual patients with AD exhibited substantially greater amounts of brain atrophy than monolingual patients in areas traditionally used to distinguish AD patients from healthy controls, specifically, the radial width of the temporal horn and the temporal horn ratio. Other measures of brain atrophy were comparable for the two groups. Bilingualism appears to contribute to increased CR, thereby delaying the onset of AD and requiring the presence of greater amounts of neuropathology before the disease is manifest.