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Research Methods

Neuroscientific Methods to Study Discourse Processes

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Almost as long as discourse psychologists have been asking questions about what mechanics of the mind give rise to language understanding, they have been asking what parts of the brain implement those mechanics. Along the way, a number of quite useful techniques have been created to peek into the brain to see how the brain processes language. These methods range from imaging techniques to visualize which parts of the brain may be working harder than others during a task, to measuring its electrical signals, to manipulating the signals themselves. This section will offer a brief overview of some of the main methods, and some of the less used ones as well. This section is not meant to be a user's guide, but rather a primer to introduce new researchers to these methods. For more exhaustive descriptions of the procedures, good starting places would be Cabeza and Kingstone's book on neuroimaging (2006) and Luck's book on event-related potentials (ERPs) (2014).

Neuroimaging

Neuroimaging methods are meant to create visualizations of the brain and to map brain activity, usually in response to the presentation of a stimulus or event. In the case of discourse psychologists, researchers are interested in how the brain engages in processing language, broadly defined. The most widely used imaging techniques to measure functional brain activity are positron emission tomography (PET) and functional magnetic resonance imaging (fMRI). Both of these methods measure neuronal activity indirectly by assessing metabolic changes in the brain during a task (e.g., reading). The standard assumption is that brain regions that have more blood are likely working harder. In PET scans, the participant is injected with a radioactive isotope that distributes itself in the blood stream, including blood in the brain. These isotopes rapidly decay setting in motion a process that emits photons. The PET scanner detects these photons, which allows their point of origin to be measured. More photons indicate more blood. In fMRI experiments, brain activity is indirectly measured by assessing changes in blood flow across the brain; specifically, the ratio of oxygenated to deoxygenated hemoglobin. This is called the blood oxygen level dependent signal (BOLD).

A higher BOLD signal in a region is assumed to mean that region is working harder; it needs more oxygenated blood to keep up with demands. (As pointed out below, however, the assumption that a higher BOLD signal means more neuronal firing may be incorrect.) Both PET and fMRI provide good spatial resolution, with PET able to resolve activity down to 5 mm^3 and fMRI able to resolve activity down to 1–3 mm^3, and even smaller than that in some high-resolution applications (Harel, 2012). In modern applications of neuroimaging of language, fMRI is a preferred method, mostly because it allows for event-related measurement of activity, is less invasive than PET, and is more accessible because MR scanners are more common than computed tomography scanners (Cabeza & Kingstone, 2006).

What kinds of questions can be asked using neuroimaging methods in language experiments? Studies have assessed what brain regions are engaged when participants access the meanings of words in isolation (Bedny, Caramazza, Grossman, Pascual-Leone, & Saxe, 2008; Hauk, Johnsrude, & Pulvermüller, 2004; Kemmerer & Gonzalez-Castillo, 2010; Petersen, Fox, Posner, Mintun, & Raichle, 1989) and embedded in discourse (Yarkoni, Speer, Balota, McAvoy, & Zacks, 2008), perform syntactic parsing (Brennan et al., 2012), build coherence relations between sets of texts (Ferstl, Neumann, Bogler, & von Cramon, 2008), produce inferences (Mason & Just, 2004), build situation models (Speer, Reynolds, Swallow, & Zacks, 2009; Whitney et al., 2009), comprehend figurative language (Rapp, Mutschler, & Erb, 2012), generate perceptual representations during discourse processing (Chow et al., 2015; Kurby & Zacks, 2013), and construct multilevel representations of discourse (Friese, Rutschmann, Raabe, & Schmalhofer, 2008). (This is, of course, not an exhaustive list.) Clearly, neuroimaging techniques are well suited to investigating where in the brain different components of language processing are possibly conducted. However, a recent study also demonstrates the power of fMRI to assess the temporal dynamics of brain activity during the experience of language processing. Silbert and colleagues (Silbert, Honey, Simony, Poeppel, & Hasson, 2014) investigated the neural systems that become active during both language production, and language comprehension. They had participants tell a 15-minute story while their brain activity was recorded with fMRI. A separate group of participants then listened to that story while their activity was also recorded. Silbert et al. (2014) identified a common set of regions in temporal cortex that became active in both cases. More impressively, they found that those regions showed correlated dynamics across time between speaking and listening participants (i.e., moment-to-moment changes in BOLD signal were correlated across participants). This suggests that not only do certain regions participate in both modes of language processing, but that they may do so in a similar fashion across time. Studies such as these show that fMRI is valuable not only for spatial localization of processing, but also informative with respect to dynamic processing.

Although a notable strength of neuroimaging techniques is spatial localization, they have less than ideal temporal resolutions (Luck, 2014). The hemodynamic response is slow, with a peak around 6–10 seconds after onset (Cabeza & Kingstone, 2006). Thus, neuroimaging is not well suited to address questions regarding millisecond timing, or shorter timecourses of processes. Through proper experimental design and statistical techniques, however, one can separate the BOLD signal from events that occur in quicker succession, such as two different words appearing in the same sentence (Yarkoni et al., 2008), or two clauses in the same paragraph (Kurby & Zacks, 2013). But, inferences about the timing of successive neural events are typically not justified. Regarding PET, its use has become less common in part because the injection of radioactive isotopes into the participant make it more invasive than is typically desired. Lastly, one must be cautious about interpreting the meaning of the BOLD signal. It is tempting to assume that an increase indicates more neuronal firing; however, research suggests that changes in the hemodynamic response in the brain may better reflect changes in local field potentials driven by dendritic activity, and perhaps not changes in axonal firing (Cabeza & Kingstone, 2006). This is important because if a region is identified to increase in activity in response to an experimental event, it is unclear if that increase is driven by neural generators in that region, or because it is receiving signals from another region, or both.

Electrophysiological and Electromagnetic Methods

Other methods record or manipulate electrical potentials or magnetic fields, produced by the brain, on the scalp of the participant while they read text. The ERP technique is a common method to measure changes in electrical activity on the scalp (Luck, 2014), whereas magnetoencephalography (MEG) is used to measure changes in magnetic fields on the scalp. Transcranial magnetic stimulation (TMS), and repetitive magnetic transcranial stimulation (rTMS) apply magnetic fields to the scalp to stimulate or inhibit the underlying brain tissue. Transcranial direct-current stimulation (tDCS) applies an electrical current to the scalp to stimulate or inhibit neuronal activity. Each will briefly be discussed in turn.

In ERP experiments, participants wear a cap with 16–128 (or more) electrodes that simultaneously record electrical activity while they read units of text. An important advantage of using ERP is that it has high temporal resolution, sampling at rates from 250 Hz up to 1000 Hz. Additionally, measurements of cognitive processing can be done "covertly"; participants need not be asked to engage in an explicit judgment task during reading. Data are plotted and analyzed in relation to the onset of an event, such as the presentation of a word. Waveforms are produced which display average voltage differences recorded from an electrode across time. Typically, deflections of the waveform are observed at different delays from the onset of an event. These deflections or components of the ERP waveform are defined in a number of ways, including by their polarity, timing, and peak onset (Luck, 2014). There are a number of such components, with the N400 and the P600 two of the most studied (Luck, 2014). The N400 is a negative deflection with a peak between 300–500 ms after event onset. The magnitude of the N400 is typically interpreted as a sign of difficulty with semantic integration, with larger magnitudes associated with higher difficulty (Kutas & Hillyard, 1980; Luck, 2014; van Berkum, Hagoort, & Brown, 1999). The P600 is a positive deflection peaking between 500–900 ms after event onset, and has been associated with difficulty with syntactic processing (Hagoort, Brown, & Groothusen, 1993; Kaan, 2007), and may indicate additional processing of the text by the reader (Hagoort et al., 1993; Kuperberg, Paczynski, & Ditman, 2011).

The ERP methodology has been used to investigate many aspects of language processing (Kaan, 2007). A common method for ERP in language comprehension is to have participants read a unit of text (e.g., sentence) and then encounter a word that fits the previous sentential or discourse context to varying degrees of acceptability. The resulting ERP components to these violations are then measured. Using this general methodology, ERPs have revealed insights about syntactic parsing (e.g., Osterhout & Holcomb, 1992), word and sentence comprehension (e.g., Kutas & Hillyard, 1983, 1984), causal inferencing and situation model processing (e.g., Kuperberg et al., 2011), integration of information into discourse representations (e.g., van Berkum et al., 1999; Yang, Perfetti, & Schmalhofer, 2007), emotion processing during reading (e.g., Holt, Lynn, & Kuperberg, 2009), and word anticipation during discourse comprehension (e.g., Otten & Van Berkum, 2008).

Although ERP methods are quite powerful, they do have two major limitations. One is that they require a large amount of trials (usually in the hundreds) to obtain a reliable estimate of electrical changes (Luck, 2014), which may be impractical. The other is the well-known fact that they do not have good spatial resolution. In brief, a signal detected at any particular location on the scalp can be generated by any location from within the brain, rendering the location of the neural generator of the signal potentially unknowable. This so-called inverse problem has been argued to be mathematically unsolvable (Luck, 2014). Some efforts have been made on this front, such as sLORETA (Pascual-Marqui, 2002), which provides a low-resolution solution to find the center of regions that may contribute to an ERP signal. But, the use of these methods is not common (but see Louwerse & Hutchinson, 2012, for an interesting use of it).

Magnetoencephalography (MEG) is very similar to EEG, except instead of measuring electrical potentials, it measures magnetic fields. MEG may have even better temporal resolution than ERP with sampling rates near 3 kHz (Schmidt & Roberts, 2009). Additionally, because MEG measures magnetic fields, it has much better spatial resolution as well. (In contrast to ERP signals, magnetic fields are not distorted by the skull.) Thus, MEG provides a powerful method to investigate neural processing of discourse with both high temporal and spatial resolution. However, a main drawback is that the maintenance of an MEG system is quite expensive as it requires supercooling equipment and a magnetically shielded chamber (Luck, 2014), and as such the use of this technique in discourse comprehension is unfortunately uncommon. It is not surprising then that most of the use of MEG with language is conducted in medical facilities that investigate the relation between neurological disorders and language functioning (Breier et al., 2004; Moseley et al., 2014). (Though there are also uses outside of medical realms, such as joke comprehension, Marinkovic et al., 2011, and second language learning, Schmidt & Roberts, 2009.)

Transcranial magnetic stimulation (TMS), and repetitive magnetic transcranial stimulation (rTMS) are methods by which magnetic fields are applied to the scalp, and thus the underlying brain tissue, to affect neuronal activity of specific brain regions. Single-pulse TMS is used to excite specific brain regions during comprehension, with the assumption that if a brain region is important for a certain language function, then exciting that region should impact how that function is carried out. While there have not been that many published studies using single-pulse TMS in the context of discourse processing to date, the technique has been used in studies of sentence understanding. Researchers in embodied sentence comprehension, for example, have taken advantage of the fact that when a TMS pulse is applied to the motor cortex, a motor response is produced (a motor-evoked potential or *MEP*). Buccino et al. (2005), for example, found that MEPs induced by single-pulse TMS applied to either the hand or foot regions of the motor strip were modulated when reading sentences about hand or foot actions. Glenberg et al. (2008) found similar effects in regard to the reading of abstract transfer sentences. In rTMS, a train of pulses are applied on the scalp, and thus the underlying brain tissue, to interfere with neural activity causing a temporary lesion. This method allows for asking whether a brain region is causally important to some language function, similar to the logic used in standard lesion studies. rTMS has been used for studies of word processing, for example showing that the application of rTMS to left primary motor cortex interferes with verb processing of right handed individuals (Repetto, Colombo, Cipresso, & Riva, 2013). rTMS has also been used to investigate higher level language processes, such as idiom comprehension (Rizzo, Sandrini, & Papagno, 2007). Although these methods are important in the investigation of language processing, they have a few important limitations. First, they are not good methods for investigating the role of brain regions below the superficial layers of cortex. Second, the effects of TMS are relatively short lived, and as such they may be inappropriate to use when investigating the maintenance and revision of representations over time

In contrast, tDCS has become more common, which provides a means of providing continuous electrical stimulation to a brain region (through the scalp) to affect processing during language tasks over time (Nozari, Arnold, & Thompson-Schill, 2014). Similar to TMS, stimulation of a brain region is assumed to enhance the functioning of that region, perhaps revealing its importance in a language task of interest. This technique has been used recently in investigations of language production (Marangolo et al., 2013). Nozari et al. (2014), for example, found that stimulation of the left prefrontal cortex, a region associated with executive functioning, caused participants to produce fewer error prone utterances compared to a sham stimulation condition. Because tDCS can stimulate tissue for longer durations than TMS, it could offer exciting applications for the investigation of situation model construction, which typically unfolds across time as the reader engages in working memory maintenance and updating processes (Zwaan & Radvansky, 1998). Additionally, tDCS is relatively cheap, in comparison to TMS or ERP setups, which makes the method potentially accessible to a large pool of researchers.

In summary, it is clear that discourse researchers have a large set of neuroscience methods available to investigate language processing. Some of these methods are well suited to asking what brain regions may contribute meaningfully to comprehension and others to investigating the neural timing of language processing. Researchers also have at their disposal methods to test causal relations between brain structures and comprehension, though at the moment the methods may be underused. Although discovery of the neural underpinnings of language comprehension is interesting in its own right, more broadly, it proves crucial for understanding how the brain implements language both practically and theoretically.

References

Bedny, M., Caramazza, A., Grossman, E., Pascual-Leone, A., & Saxe, R. (2008). Concepts are more than percepts: The case of action verbs. *The Journal of Neuroscience, 28*, 11347–11353.

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*(4), 1308–1316. http://doi.org/http://dx.doi.org.ezproxy.gvsu.edu/10.1016/j.neuroimage.2004.07.069.

Brennan, J., Nir, Y., Hasson, U., Malach, R., Heeger, D. J., & Pylkkanen, L. (2012). Syntactic structure building in the anterior temporal lobe during natural story listening. *Brain and Language, 120*(2), 163–173. http://doi.org/10.1016/j.bandl.2010.04.002.

Buccino, G., Riggio, L., Melli, G., Binkofski, F., Gallese, V., & Rizzolatti, G. (2005). Listening to action-related sentences modulates the activity of the motor system: A combined TMS and behavioral study. *Cognitive Brain Research, 24*(3), 355–363. http://doi.org/http://dx.doi.org.ezproxy.gvsu.edu/10.1016/j.cogbrainres.2005.02.020.

Cabeza, R., & Kingstone, A. (Eds). (2006). *Handbook of functional neuroimaging of cognition (2nd ed.)*. Cambridge, MA: MIT Press. Retrieved from http://search.proquest.com.ezproxy.gvsu.edu/psycinfo/docview/621493890/F05BCBAF33B54B34PQ/1?.

Chow, H. M., Mar, R. A., Xu, Y., Liu, S., Wagage, S., & Braun, A. R. (2015). Personal experience with narrated events modulates functional connectivity within visual and motor systems during story comprehension. *Human Brain Mapping, 36*(4), 1494–1505. http://doi.org/10.1002/hbm.22718.

Ferstl, E. C., Neumann, J., Bogler, C., & von Cramon, D. Y. (2008). The extended language network: A meta-analysis of neuroimaging studies on text comprehension. *Human Brain Mapping, 29*(5). http://doi.org/10.1002/hbm.20422.

Friese, U., Rutschmann, R., Raabe, M., & Schmalhofer, F. (2008). Neural indicators of inference processes in text comprehension: An event-related functional magnetic resonance imaging study. *Journal of Cognitive Neuroscience, 20*(11), 2110–2124. http://doi.org/http://dx.doi.org.ezproxy.gvsu.edu/10.1162/jocn.2008.20141.

Glenberg, A. M., Sato, M., Cattaneo, L., Riggio, L., Palumbo, D., & Buccino, G. (2008). Processing abstract language modulates motor system activity. *The Quarterly Journal of Experimental Psychology*, *61*, 905–919.

Hagoort, P., Brown, C., & Groothusen, J. (1993). The syntactic positive shift (SPS) as an ERP measure of syntactic processing. *Language and Cognitive Processes*, *8*(4), 439–483. http://doi.org/http:// dx.doi.org.ezproxy.gvsu.edu/10.1080/01690969308407585.

Harel, N. (2012). Ultra high resolution fMRI at ultra-high field. *NeuroImage*, *62*(2), 1024–1028. http:// doi.org/10.1016/j.neuroimage.2012.01.018.

Hauk, O., Johnsrude, I., & Pulvermüller, F. (2004). Somatotopic representation of action words in human motor and premotor cortex. *Neuron*, *41*, 301–307.

Holt, D. J., Lynn, S. K., & Kuperberg, G. R. (2009). Neurophysiological correlates of comprehending emotional meaning in context. *Journal of Cognitive Neuroscience*, *21*(11), 2245–2262. http://doi. org/http://dx.doi.org.ezproxy.gvsu.edu/10.1162/jocn.2008.21151.

Kaan, E. (2007). Event-related potentials and language processing: A brief overview. *Language and Linguistics Compass*, *1*(6), 571–591. http://doi.org/http://dx.doi.org.ezproxy.gvsu.edu/10.1111/ j.1749-818X.2007.00037.x.

Kemmerer, D., & Gonzalez-Castillo, J. (2010). The two-level theory of verb meaning: An approach to integrating the semantics of action with the mirror neuron system. *Brain and Language*, *112*(1), 54–76. http://doi.org/http://dx.doi.org.ezproxy.gvsu.edu/10.1016/j.bandl.2008.09.010.

Kuperberg, G. R., Paczynski, M., & Ditman, T. (2011). Establishing causal coherence across sentences: An ERP study. *Journal of Cognitive Neuroscience*, *23*(5), 1230–1246. http://doi.org/http:// dx.doi.org.ezproxy.gvsu.edu/10.1162/jocn.2010.21452.

Kurby, C. A., & Zacks, J. M. (2013). The activation of modality-specific representations during discourse processing. *Brain and Language*, *126*, 338–349.

Kutas, M., & Hillyard, S. A. (1980). Reading senseless sentences: Brain potentials reflect semantic incongruity. *Science*, *207*(4427), 203–205. http://doi.org/http://dx.doi.org.ezproxy.gvsu.edu/10.1126/ science.7350657.

Kutas, M., & Hillyard, S. A. (1983). Event-related brain potentials to grammatical errors and semantic anomalies. *Memory & Cognition*, *11*(5), 539–550. http://doi.org/http://dx.doi.org.ezproxy.gvsu. edu/10.3758/BF03196991.

Kutas, M., & Hillyard, S. A. (1984). Event-related brain potentials (ERPs) elicited by novel stimuli during sentence processing. *Annals of the New York Academy of Sciences*, *425*, 236–241. http:// doi.org/http://dx.doi.org.ezproxy.gvsu.edu/10.1111/j.1749-6632.1984.tb23540.x.

Louwerse, M., & Hutchinson, S. (2012). Neurological evidence linguistic processes precede perceptual simulation in conceptual processing. *Frontiers in Psychology: Cognitive Science*, *3*, 385. http:// doi.org/10.3389/fpsyg.2012.00385.

Luck, S. J. (2014). *An introduction to the event-related potential technique (2nd ed.)*. Cambridge, MA: MIT Press.

Mahon, B. Z., & Caramazza, A. (2008). A critical look at the embodied cognition hypothesis and a new proposal for grounding conceptual content. *Journal of Physiology - Paris*, *102*, 59–70.

Marangolo, P., Fiori, V., Calpagnano, M. A., Campana, S., Razzano, C., Caltagirone, C., & Marini, A. (2013). tDCS over the left inferior frontal cortex improves speech production in aphasia. *Frontiers in Human Neuroscience*, *7*. Retrieved from http://search.proquest.com.ezproxy.gvsu.edu/psycinfo/ docview/1450175543/C74D73D76329440DPQ/1?.

Marinkovic, K., Baldwin, S., Courtney, M. G., Witzel, T., Dale, A. M., & Halgren, E. (2011). Right hemisphere has the last laugh: Neural dynamics of joke appreciation. *Cognitive, Affective and Behavioral Neuroscience*, *11*(1), 113–130.

Mason, R. A., & Just, M. A. (2004). How the brain processes causal inferences in text. *Psychological Science*, *15*(1), 1–7. http://doi.org/10.1111/j.0963-7214.2004.01501001.x.

Moseley, R. L., Pulvermüller, F., Mohr, B., Lombardo, M. V., Baron-cohen, S., & Shtyrov, Y. (2014). Brain routes for reading in adults with and without autism: EMEG evidence. *Journal of Autism and Developmental Disorders*, *44*(1), 137–153. http://doi.org/http://dx.doi.org.ezproxy.gvsu. edu/10.1007/s10803-013-1858-z.

Nozari, N., Arnold, J. E., & Thompson-Schill, S. L. (2014). The effects of anodal stimulation of the left prefrontal cortex on sentence production. *Brain Stimulation*, *7*(6), 784–792. http://doi. org/10.1016/j.brs.2014.07.035.

Osterhout, L., & Holcomb, P. J. (1992). Event-related brain potentials elicited by syntactic anomaly. *Journal of Memory and Language*, *31*(6), 785–806. http://doi.org/http://dx.doi.org.ezproxy.gvsu.edu/10.1016/0749-596X(92)90039-Z.

Otten, M., & Van Berkum, J. J. A. (2008). Discourse-based word anticipation during language processing: Prediction or priming? *Discourse Processes*, *45*(6), 464–496. http://doi.org/http://dx.doi.org.ezproxy.gvsu.edu/10.1080/01638530802356463.

Pascual-Marqui, R. D. (2002). Standardized low-resolution brain electromagnetic tomography (sLORETA): Technical details. *Methods and Findings in Experimental and Clinical Pharmacology, 24 Suppl D*, 5–12.

Petersen, S. E., Fox, P. T., Posner, M. I., Mintun, M., & Raichle, M. E. (1989). Positron emission tomographic studies of the processing of singe words. *Journal of Cognitive Neuroscience*, *1*(2), 153–170. http://doi.org/10.1162/jocn.1989.1.2.153.

Pylyshyn, Z. W. (1981). The imagery debate: Analogue media versus tacit knowledge. *Psychological Review*, *88*, 16–45.

Rapp, A. M., Mutschler, D. E., & Erb, M. (2012). Where in the brain is nonliteral language? A coordinate-based meta-analysis of functional magnetic resonance imaging studies. *NeuroImage*, *63*(1), 600–610. http://doi.org/10.1016/j.neuroimage.2012.06.022.

Repetto, C., Colombo, B., Cipresso, P., & Riva, G. (2013). The effects of rTMS over the primary motor cortex: The link between action and language. *Neuropsychologia*, *51*(1), 8–13. http://doi.org/http://dx.doi.org.ezproxy.gvsu.edu/10.1016/j.neuropsychologia.2012.11.001.

Rizzo, S., Sandrini, M., & Papagno, C. (2007). The dorsolateral prefrontal cortex in idiom interpretation: An rTMS study. *Brain Research Bulletin*, *71*(5), 523–528. http://doi.org/http://dx.doi.org.ezproxy.gvsu.edu/10.1016/j.brainresbull.2006.11.006.

Schmidt, G. L., & Roberts, T. P. (2009). Second language research using magnetoencephalography: A review. *Second Language Research*, *25*(1), 135–166. http://doi.org/http://dx.doi.org.ezproxy.gvsu.edu/10.1177/0267658308098999.

Silbert, L. J., Honey, C. J., Simony, E., Poeppel, D., & Hasson, U. (2014). Coupled neural systems underlie the production and comprehension of naturalistic narrative speech. *Proceedings of the National Academy of Sciences of the United States of America*, *111*(43), E4687–96. http://doi.org/10.1073/pnas.1323812111.

Slotnick, S. (2013). *Controversies in cognitive neuroscience*. New York, NY: Palgrave Macmillan. Retrieved from http://search.proquest.com.ezproxy.gvsu.edu/psycinfo/docview/1312427287/39C421B2F2DB4CA8PQ/2?.

Speer, N. K., Reynolds, J. R., Swallow, K. M., & Zacks, J. M. (2009). Reading stories activates neural representations of visual and motor experiences. *Psychological Science*, *20*, 989–999.

van Berkum, J. J. A., Hagoort, P., & Brown, C. M. (1999). Semantic integration in sentences and discourse: Evidence from the N400. *Journal of Cognitive Neuroscience*, *11*, 657–671.

Whitney, C., Huber, W., Klann, J., Weis, S., Krach, S., & Kircher, T. (2009). Neural correlates of narrative shifts during auditory story comprehension. *NeuroImage*, *47*(1). http://doi.org/10.1016/j.neuroimage.2009.04.037.

Yang, C. L., Perfetti, C. A., & Schmalhofer, F. (2007). Event-related potential indicators of text integration across sentence boundaries. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *33*(1), 55–89. http://doi.org/http://dx.doi.org.ezproxy.gvsu.edu/10.1037/0278-7393.33.1.55.

Yarkoni, T., Speer, N. K., Balota, D. A., McAvoy, M. P., & Zacks, J. M. (2008). Pictures of a thousand words: Investigating the neural mechanisms of reading with extremely rapid event-related fMRI. *NeuroImage*, *42*(2), 973–987. http://doi.org/10.1016/j.neuroimage.2008.04.258.

Zwaan, R. A., & Radvansky, G. A. (1998). Situation models in language comprehension and memory. *Psychological Bulletin*, *123*, 162–185.