Foreword to the Special Issue "Before the N400: Early Latency Language ERPs"

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As cognitive and neural models of language processing have developed, so have the ranks of language-related ERP components. This special issue is intended to showcase current cutting-edge research on this topic, with an emphasis on those ERP components peaking earlier than the N400, and their implications for neurocognitive language models. Both reading and speech comprehension are addressed due to the close relationship between these two topics.

As the contents of this special issue illustrate, the high temporal resolution of the ERP methodology makes it especially suitable for illuminating three fundamental questions about the language comprehension process: 1) How early is semantics? 2) In what order do these cognitive operations occur in? 3) To what extent are the cognitive operations serial and to what extent are they in parallel?

Studying neural models of language used to be a simple affair. The original neurological model, dating back to the dawn of functional neuroanatomy, consisted of little more than Broca's area for output and syntax (Broca, 1865) and Wernicke's area for input and semantics (Wernicke, 1874). Aside from a later elaboration that added the angular gyrus for reading (Dejerine, 1891; Dejerine, 1892), this simple model dominated the study of language for many years. Even today, introductory psychology students the world over learn little more than this body of work, as interpreted by Geschwind (1965). In a final addition, further neurological studies subsequently suggested that the inferior temporal lobe might also play a role in language and termed it the basal language area (Lüders et al., 1986).

The development of functional neuroimaging has made it possible to build on these observations by providing greater spatial resolution, on the order of millimeters. In doing so, it has also provided persuasive evidence of specialized subareas within the broad boundaries established by lesion studies. For example, a visual word form area (VWFA) has been identified (Cohen et al., 2000) in the basal language area that appears to mediate a prelexical level of analysis (Dehaene, Cohen, Sigman, & Vinckier, 2005). Furthermore, such work has provided a strong neural basis for cognitive models, such as the dual route cascaded or DRC model (Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001), that suggest that reading involves both a lexical route that directly recognizes visual word forms as well as a phonological route that involves first translating them to an auditory code.

While functional neuroimaging techniques have provided crucial improvements in spatial resolution, they share in common with lesion techniques the problem of limited temporal resolution. For example, an ongoing debate regarding the VWFA concerns

whether its sensitivity to types of stimuli other than visual words indicates that it is not truly specific to visual word forms (Price & Devlin, 2003; Price & Devlin, 2004) or whether such activity reflects later top-down influences as associated visual word form information is activated (Cohen & Dehaene, 2004; Dehaene, Le, Poline, Le Bihan, & Cohen, 2002).

Event-related potentials (ERPs) have provided a complementary methodology that provides high temporal resolution, on the order or milliseconds (see Handy, 2004; Luck, 2005). ERPs are the electrical potentials that are time-locked to an event of interest. They are isolated from the overall electroencephalographic activity by signal averaging, combining the recordings from repeated trials of the conditions of interest to average out activity unrelated to the event of interest. They are thought to reflect the accumulation of voltage differentials in the apical dendrites of neurons. Although they provide detailed temporal information, spatial information is limited to inferences drawn from computer models of the scalp topographies of the potential fields (Scherg, 1990).

A seminal report (Kutas & Hillyard, 1980) marked the dawn of modern event-related potential (ERP) studies of language with the discovery of the N400, which proved to be a sensitive indicator of semantic processing. Although its generator site(s) has yet to be conclusively determined, a leading school of thought is indeed that it is produced in the vicinity of Wernicke's area (Van Petten & Luka, 2006), although others favor the basal language area (Friederici, 2002). Likewise, syntactic manipulations tended to be associated with a P600 (Osterhout & Holcomb, 1992). The P600's generator is likewise unclear but some view it as coming from the inferior frontal regions near Broca's area (Friederici, 2002).

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current cutting-edge research on this topic, with an emphasis on those ERP components peaking earlier than the N400, and their implications for neurocognitive language models. Both reading and speech comprehension are addressed due to the close relationship between these two topics.

An initial review of the behavioral literature, especially that of eye movement measures, makes the case that it is reasonable to expect that substantial language processing can be expected in reading prior to 400 ms (Rayner & Clifton, in press). This review is then complemented by a treatment of early latency reading ERP components and their implications for cognitive models of reading (Dien, in press).

As the contents of this special issue illustrate, the high temporal resolution of the ERP methodology make it especially suitable for illuminating three fundamental questions about the language comprehension process: 1) How early is semantics? 2) In what order do these cognitive operations occur in? 3) To what extent are the cognitive operations serial and to what extent are they in parallel?

The question of "how early is semantics" is essentially a question about what is the nature of semantics itself. Is semantic information a distinct domain as suggested by some models (Coltheart et al., 2001; Forster, 1979; Reichle, Rayner, & Pollatsek, 2003; Van Orden, Pennington, & Stone, 1990) or is it merely implicit in broader representational systems (Rumelhart, 1977)? Some of the present studies suggest that aspects of semantics are processed earlier than the N400 in reading and are reflected in ERP components associated with other domains of information processing (Friedrich & Schild, in press; Frishkoff, Perfetti, & Westbury, in press; Kissler, Herbert, Winkler, & Junghofer, in press; Scott, O'Donnell, Leuthold, & Sereno, in press), thus favoring the latter position.

The question of "in what order do these cognitive operations occur in" is one that has resonated in the ongoing debates about modularity in language processing. According to some views, different levels of language processing are encapsulated and do not interact (Fodor, 1983; Fodor, 1985; Forster, 1979) while others suggest they do indeed interact to varying degrees (Coltheart et al., 2001; Reichle et al., 2003; Van Orden & Goldinger, 1994). Even models that do allow for interaction between semantics and syntax may not allow for predictive top-down influences (Marslen-Wilson & Tyler, 1980). Studies in this special issue favor the latter position in reading (Angrilli & Spironelli, in press; Frishkoff et al., in press; Segalowitz & Zheng, in press) and speech comprehension (Ashby, Sanders, & Kingston, in press; Astheimer & Sanders, in press; Friedrich & Schild, in press; Newman & Connolly, in press; Tan & Molfese, in press).

The related question of "to what extent are the cognitive operations serial and to what extent are they in parallel" echoes broader disputes currently embroiling cognitive psychology. In the reading literature, they are represented by models that envision consecutive stages of processing (Coltheart et al., 2001; Forster, 1979; Reichle et al., 2003) versus those that envision parallel distributed connectionistic networks (Rumelhart, 1977; Van Orden et al., 1990). Studies in this special issue favor the former position in reading (Angrilli & Spironelli, in press; Frishkoff et al., in press; Hauk, Pulvermüller, Ford, Marslen-Wilson, & Davis, in press; Proverbio, Adorni, & Zani, in press) and speech comprehension (Ashby et al., in press; Friedrich & Schild, in press; Tan & Molfese, in press).

Of course, the articles address a range of issues beyond these fundamental big picture questions. Angrilli and Spironelli (in press) look at developmental changes in the laterality of reading processes. Ashby, Sanders, and Kingston (in press) examine the role of phonemic information in the earliest orthographic analyses. Astheimer and

Sanders (in press) report on temporal attention effects on speech comprehension. Friedrich, Schild, and Röder (in press) make the case for a sensory amodal stage of phonological processing. Frishkoff, Perfetti, and Westbury (in press) isolate neural correlates of learning by examining frontier words that are only partially known. Hauk, Pulvermüller, Ford, Marslen-Wilson, and Davis (in press) use sophisticated regression analyses to study the early latency effects of orthographic neighborhood and provide a detailed tutorial on their methods. Kissler, Herbert, Winkler, and Junghofer (in press) show that an early latency correlate of emotional value can be evoked by words, not just pictures. Newman and Connolly (in press) probe phonological attentional effects on speech comprehension. Proverbio, Adorni, and Zani (in press) discover that even fluent bilinguals show strong differences between responses to their two languages. Scott, O'Donnell, Leuthold, and Sereno (in press) identify very early latency interactions between emotion and frequency in reading responses. Segalowitz and Zheng (in press) find semantic priming effects at even the very earliest stages of word processing. Finally, Tan and Molfese (in press) report on the developmental time course of syntactic classes to speech.

The literature on the neurocognitive basis of language comprehension is rapidly evolving. The reports in this special issue bear witness that the ERP methodology can provide vivid insights in this enterprise. It is hoped that this corpus can serve as an opportunity to consider the state of the art and to thus encourage further progress on this topic and to provide a resource in this effort. As these studies attest, ERP studies are revealing an increasingly deep view of the complex word comprehension processes that allow for nearly effortless understanding of the elaborate code that is language.

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