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Hemispheric asymmetry in event knowledge activation during incremental language comprehension: A visual half-field ERP study

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ABSTRACT

During incremental language comprehension, the brain activates knowledge of described events, including knowledge elements that constitute semantic anomalies in their linguistic context. The present study investigates hemispheric asymmetries in this process, with the aim of advancing our understanding of the neural basis and functional properties of event knowledge activation during incremental comprehension. In a visual half-field event-related brain potential (ERP) experiment, participants read brief discourses in which the third sentence contained a word that was either highly expected, semantically anomalous but related to the described event (Event-Related), or semantically anomalous but unrelated to the described event (Event-Unrelated). For both visual fields of target word presentation, semantically anomalous words elicited N400 ERP components of greater amplitude than did expected words. Crucially, Event-Related anomalous words elicited a reduced N400 relative to Event-Unrelated anomalous words only with left visual field/right hemisphere presentation. This result suggests that right hemisphere processes are critical to the activation of event knowledge elements that violate the linguistic context, and in doing so informs existing theories of hemispheric asymmetries in semantic processing during language comprehension. Additionally, this finding coincides with past research suggesting a crucial role for the right hemisphere in elaborative inference generation, raises interesting questions regarding hemispheric coordination in generating event-specific linguistic expectancies, and more generally highlights the possibility of functional dissociation of event knowledge activation for the generation of elaborative inferences and for linguistic expectancies.

1. Introduction

Language often describes scenarios or events. Comprehending such language entails mapping between linguistic input and knowledge stored in semantic memory of the type of event described, such as the typical event location, entities and actions involved, and temporal and causal relations. Research suggests that event knowledge supports incremental (i.e., word-by-word) language comprehension, including linguistic expectancy generation (Altmann and Mirković, 2009; Elman, 2009; McRae and Matsuki, 2009). Additionally, event knowledge activation can extend beyond those elements expected to appear in the unfolding sentence to include elements that constitute semantic anomalies in sentence context (Metusalem et al., 2012). Given this complex interplay between linguistic input and event knowledge, specifying the neural basis of event knowledge activation during incremental comprehension is an important goal. The present study advances this goal by investigating asymmetries across the cerebral hemispheres in the activation of semantic information that is related to a described event but is semantically anomalous in sentence context. While understanding the neural basis of event knowledge activation is important in its own right, the utility of this investigation extends further; against the backdrop of previous research suggesting systematic functional asymmetries across the hemispheres in the activation of semantic information triggered by linguistic input, this investigation informs our understanding of the functional properties of event knowledge activation more generally. The present study thus examines event knowledge activation with respect to both its neural basis and functional profile.

1.1. Activating event knowledge during incremental comprehension

Sentence and discourse comprehension can be characterized as construction of a mental representation of the described scenario or event, often called a mental or situation model (Johnson-Laird, 1983; Van Dijk and Kintsch, 1983; Zwaan and Radvansky, 1998).

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Constructing such representations involves integrating linguistic input with general knowledge stored in semantic memory of the type of event described, and comprehenders deploy this knowledge to guide comprehension as a sentence unfolds word-by-word (Altmann and Mirković, 2009; Elman, 2009; McRae and Matsuki, 2009). For example, the influence of event knowledge on the processing of post-verbal patient nouns has been demonstrated in reading times (Bicknell et al., 2010; Matsuki et al., 2011), anticipatory looking behavior in the Visual World Paradigm (Borovsky et al., 2012; Kamide et al., 2003; Kukona et al., 2011) and event-related brain potentials (ERPs; Bicknell et al., 2010). Bicknell et al.'s participants read sentences such as *The mechanic checked the brakes* or *The journalist checked the brakes*, in which the critical patient noun *brakes* is congruent with knowledge of what a mechanic might check, but is incongruent with knowledge of what a journalist might check. They found that the congruence of the patient noun with the event implied by the combination of the preceding agent and verb influenced the amplitude of the N400 ERP component. The N400 is a negative-going deflection in the ERP waveform peaking around 400 ms after the onset of a word or other potentially meaningful stimulus, and its amplitude is inversely related to the degree to which the stimulus aligns with or is expected in its context (Kutas and Hillyard, 1980, 1984; see Kutas and Federmeier (2000, 2011) for review) – the greater the semantic fit between a word and its context, the smaller the N400 (assuming other factors are held constant). Bicknell et al. found that N400 amplitude was smaller for congruent relative to incongruent patient nouns, indicating that the brain's response to these words was affected by the fit between the word and the event implied by the preceding sentential context within several hundred milliseconds of word onset.

Additional sentence comprehension research has suggested that event knowledge influences the processing of syntactic structures (Hare et al., 2009a; McRae et al., 1998) and that grammatical cues such as verb aspect serve to differentially activate event knowledge (Ferretti et al., 2007). Outside of sentence comprehension research, lexical priming studies have shown that processing of isolated words activates knowledge of events with which those words are associated (Chwilla and Kolk, 2005; Hare et al., 2009b; McRae et al., 2005), suggesting that activating event knowledge is a central component of the brain's response to individual words as well as sentences.

Noting the centrality of event knowledge to incremental comprehension, Altmann and Mirković (2009) assert that comprehension fundamentally entails mapping between sentence and event structures in the service of predicting how the language (and described event) will unfold in time. This notion highlights an interesting question with respect to event knowledge activation during incremental comprehension. Many concepts might relate to the type of event being described, but at a specific point in a sentence, only some (or none) of these will be expected to appear in the immediately upcoming linguistic input. Is real-time event knowledge activation limited to only these elements? Metusalem et al. (2012) investigated this question in an ERP experiment in which participants read three-sentence discourses describing typical events. The third sentence always presented a sentence-medial word that was either strongly expected (Expected), related to the described event but semantically anomalous in sentence context (Event-Related), or unrelated to the described event and semantically anomalous in sentence context (Event-Unrelated; e.g., *A huge blizzard swept through town last night. My kids ended up getting the day off from school. They spent the whole day outside building a big* [*snowman*/*jacket*/*towel*] *in the front yard*, in which both *jacket* and *towel* are semantically anomalous, but *jacket* is event-related by virtue of being likely to be worn by children playing in the snow). Metusalem et al. found a three-way split in amplitude of the N400, with Expected targets eliciting the smallest N400, Event-Unrelated targets eliciting the largest N400, and Event-Related targets eliciting an intermediate N400. This finding has been replicated (Amsel et al., 2015; see Huettig (2015). Metusalem et al. interpreted N400 reduction for the Event-Related targets as indicating that at any point in a sentence the real-time activation of event knowledge extends beyond those words that are expected to appear to include words that are semantically anomalous in sentence context.

During incremental comprehension, how does the brain activate contextually anomalous but event-related information? The present study addresses this question by investigating if and how the cerebral hemispheres differ with respect to this process. As will now be reviewed, the cerebral hemispheres appear to exhibit functional asymmetries in the activation of semantic information during language comprehension. In the context of this research, the present study additionally advances our understanding the functional properties of event knowledge activation.

1.2. Hemispheric asymmetries in language comprehension

Hemispheric asymmetries in language have been appreciated since the early discoveries by Broca (1861) and Wernicke (1874) of profound language deficits following lesion to only the left hemisphere. Much subsequent research has been based on a view of the left hemisphere as the dominant hemisphere for language, although modern functional imaging has made clear that language processing is supported by a complex bilateral brain network (Gernsbacher and Kaschak, 2003; Grodzinsky and Friederici, 2006; Hickok and Poeppel, 2007; Price, 2012). Within this network, the left and right hemispheres exhibit systematic functional asymmetries in semantic processing during comprehension.

Processing of a word in sentence context is highly sensitive to the message-level meaning of the sentence or discourse. ("Message-level" meaning refers to the propositional semantic content of a sentence or discourse abstracted away from the words and syntactic structures used to convey that meaning). Early work suggested that only the left hemisphere is sensitive to message-level semantic cues in the processing words in sentences and discourse (e.g., Faust et al., 1993; see Faust (1998) for review), though this view was soon revised to include a degree of sensitivity to message-level cues by the right hemisphere (Chiarello et al., 2001). ERP studies have made clear that the both hemispheres are sensitive to message-level cues, but in different ways (Coulson et al., 2005; Federmeier and Kutas, 1999b; Federmeier et al., 2005; Wlotko and Federmeier, 2007, 2013). ERP studies on hemispheric asymmetries in the semantic processing of words in sentence and discourse contexts typically focus on the N400 component and utilize visual half-field presentation of critical words. Visual half-field methods lateralize presentation of a target stimulus to either the right or left visual field. Only the hemisphere contralateral to the visual field of presentation receives direct sensory input, and processing proceeds unilaterally through area V2; the ipsilateral hemisphere receives information only via subsequent callosal transfer, which is delayed and can result in loss of information fidelity (see discussion by Banich (2003)). Visual half-field presentation thus provides a processing advantage to the contralateral hemisphere, and observation of differing responses to the same stimulus when presented to the left versus right visual fields can support inferences regarding hemispheric asymmetries in processing.[1] Visual half-field presentation methods have been

[1] It is important to note that due to interhemispheric communication in the healthy adult brain, studies using visual half-field presentation methods cannot support strong inferences that attribute a process exclusively to one hemisphere. Visual half-field methods provide a processing advantage to the contralateral hemisphere but do not rule out involvement of the ipsilateral hemisphere. No claims in this paper regarding visual half-field studies are meant to imply that a cognitive process is carried out exclusively in one hemisphere or the other, but only that one hemisphere appears to play a greater or more central role than the other hemisphere in that process.