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Research Report

Summing it up: Semantic activation processes in the two hemispheres as revealed by event-related potentials

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ABSTRACT

The coarse coding hypothesis suggests that semantic activation is broader in the right hemisphere, affording it an advantage over the left hemisphere for the activation of distantly related concepts or multiple meanings of lexically ambiguous words. Behavioral studies investigating coarse coding have yielded mixed results, perhaps in part because such measures sum across multiple processing stages. To more directly tap into the semantic activation processes that are the focus of the coarse coding hypothesis, the current study combined a visual half-field summation-priming paradigm with the measurement of event-related potentials (ERPs). Two primes converged onto a lateralized, unambiguous target (e.g., *lion–stripes–tiger*) or diverged onto different meanings of a lateralized, ambiguous target (e.g., *kidney–piano–organ*); in both cases, the primes were related to one another only through the target. In two experiments, participants either made lexical decisions to the targets or made a semantic-relatedness judgment between primes and target. Priming was measured as reductions in the amplitude of the N400, an ERP component that has been specifically linked to meaning activation and that showed semantic-level priming patterns in both of the tasks used in the present study. Counter to the predictions of the coarse coding hypothesis, equivalent N400 summation priming was observed for targets in the two visual fields, in both types of triplets and in both experiments. Thus, the current results fail to support the hypothesis that semantic activation patterns differ in the two hemispheres and point, instead, to other sources for observed asymmetries in verbal processing.

1. Introduction

Given increasing evidence that not only the left cerebral hemisphere (LH) but also the right (RH) contributes to language comprehension (e.g., Beeman and Chiarello, 1998), a number of frameworks have been put forward to explain the nature of the differences between each hemisphere's processing of language input. Perhaps the most prominent of these is the *coarse coding hypothesis* (Jung-Beeman, 2005), which posits that hemispheric asymmetries in language processing might arise from differences in the breadth of semantic activation. According to this view, when a word is encountered in context, the LH strongly activates a restricted set of contextually delineated concepts, whereas the RH weakly activates a broad set of concepts, including those that may be more loosely linked to the context. It has been suggested that although

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coarse coding in the RH renders it less effective than the LH for the kind of rapid meaning selection and interpretation that characterizes many aspects of everyday language, the activation of more distantly linked information can confer an advantage for dealing with the multiple, sometimes incompatible interpretations that may arise during the processing of jokes and other types of figurative language (e.g., Coulson and Williams, 2005). Coarse coding has also been linked to a critical role for the RH in inference processing (Beeman, Bowden and Gernsbacher, 2000) and creative problem solving (Bowden and Jung-Beeman, 2003; Jung-Beeman, 2005).

Evidence supporting this framework has come from studies of semantic priming (facilitation for a target word when preceded by an associated and/or semantically related prime word; e.g., Neely, 1991) that have used the visual half-field (VF) technique. In this technique, stimuli are presented in the visual periphery, such that they are apprehended and initially processed by the contralateral cerebral hemisphere (i.e., stimuli presented in the right visual field (RVF) are initially apprehended by the LH and stimuli presented in the left visual field (LVF) are initially apprehended by the RH). Despite the potential for information transfer between the two hemispheres via the corpus callosum, the hemisphere that receives the stimulus directly has a processing advantage in terms of information quality and time. This technique has been extensively employed in brain-intact individuals to uncover hemispheric asymmetries in semantic priming. For instance, several studies have suggested that whereas strongly related primes (e.g., those that both share semantic features with and are lexically associated to the targets; *sofa–chair*) facilitate processing in both hemispheres, weakly related primes (e.g., those that are unassociated with the targets but do share some feature overlap; *lamp–chair*) facilitate processing only in the RH (Chiarello, Burgess, Richards and Pollock, 1990; Chiarello and Richards, 1992). Results like these point to a role for the RH in appreciating more distant semantic relationships between words. Additional evidence in support of coarse coding has come from a study of summation priming (Beeman et al., 1994), in which participants were presented with a series of three primes that were either weakly related (*white–ceremony–tuxedo*) or unrelated (*soap–tunnel–mouse*) to a lateralized target (*wedding*). Naming accuracy for the targets preceded by weak associates was facilitated only with LVF/RH presentations, again suggesting a RH benefit for integrating across multiple, weakly related concepts.

Support for coarse coding has also been seen in studies looking at the processing of lexically ambiguous words. For example, Burgess and Simpson (1988) investigated when and how the two hemispheres activate the dominant (more frequent) and subordinate (less frequent) meaning of an ambiguous prime. The LH activated all meanings of the ambiguous prime at a shorter SOA (35 ms), but by a longer SOA (750 ms) only the dominant meaning remained active. However, activation of both meanings was seen in the RH even at the longer SOA, suggesting that the RH maintains a broader range of meanings, including those that may have been eliminated by the more selective LH. Another study used the summation-priming paradigm to further investigate if there are RH benefits for activating multiple, incompatible meanings of an ambiguous word (Faust and Lavidor, 2003). In two experiments (using lexical decision and semantic judgment tasks), a lateralized target followed two primes, which either converged onto the dominant (e.g., *maybe–perhaps–might*) or the subordinate meaning (*strength–power–might*) of an ambiguous target or diverged onto two different meanings of the ambiguous target (*maybe–strength–might*). The results showed that whereas the LH benefited most in the convergent condition, the RH benefited most in the divergent condition, again alluding to a RH benefit for integrating across multiple, distinct meanings.

However, other studies manipulating semantic distance in terms of the number of intervening items in semantic memory between a prime and target have not always yielded results consistent with the idea that facilitation spreads further in the RH than in the LH. For instance, Richards and Chiarello (1995) examined naming latencies for word pairs that were associated either directly (e.g., *water–drink*) or indirectly (e.g., *soap–drink*, which are related through the mediating concept *water*). The coarse coding hypothesis should predict a RH advantage for processing the more semantically distant mediated pairs. Instead, although overall priming was greater for direct than for mediated associates, this pattern was equivalent in the two visual fields across a range of stimulus onset asynchronies (50, 250, and 750 ms). In particular, there was no indication that processing of the mediated pairs was facilitated with presentation to the LVF/RH. Livesay and Burgess (2003) obtained a similar pattern of results for mediated prime–target pairs that were likely to be experienced in the same context (e.g., *bat* and *bounce*, mediated by a common context, *ball*) and for those that were not (e.g., *summer* and *snow*, mediated by *winter*). Equivalent amounts of mediated priming (relative to an unrelated baseline) were seen in the two VFs for both types of pairs, leading the authors to suggest that lexical representations in the two hemispheres might be similar.

In a prior study (Kandhadai and Federmeier, 2007), we set out to examine the basis for the discrepancy between studies that have found results consistent (Beeman et al., 1994; Faust and Lavidor, 2003) and inconsistent (Richards and Chiarello, 1995; Livesay and Burgess, 2003) with the hypothesis of coarse coding in the RH. We employed a summation-priming paradigm using both lexically ambiguous and unambiguous targets. Participants viewed triplets of words, including two sequentially presented central primes that were each either related or unrelated to the following lateralized target. When both primes were related to the target (the "double prime" condition), they either diverged onto multiple, different meanings of an ambiguous target (e.g., *kidney–piano–organ*; similar to the divergent condition in Faust and Lavidor, 2003) or converged onto the single meaning of an unambiguous target (e.g., *lion–stripes–tiger*). In both triplet types, the two primes were never directly related to each other, such that the relationship between the primes was similar to the mediated priming conditions used in prior studies (e.g., Richards and Chiarello, 1995). The coarse coding hypothesis would predict a RH benefit (relative to the LH) for integrating across multiple, distantly related primes, perhaps especially in the divergent (ambiguous) condition.

We used two different tasks in our study to allow us to further examine the locus of any priming effects we might observe. Our stimuli were based on those previously used by Balota and Paul (1996) to examine whether priming arises at lexical (word form) or semantic (word meaning) levels of processing. At the level of word form, both unambiguous (*tiger*) and ambiguous (*organ*) targets are assumed to have a single representation. However, at