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The brain's hemispheres and controlled search of the lexicon: Evidence from fixated words and pseudowords

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ABSTRACT

Difference between the brain's hemispheres in efficiency of intentional search of the mental lexicon with phonological, orthographic, and semantic strategies was investigated. Letter strings for lexical decision were presented at fixation, with a lateralized distractor to the LVF or RVF. Word results revealed that both hemispheres were capable of using each of the three strategies, but the right hemisphere had better baseline processing of orthography and was better at processing semantics. Pseudoword results supported the right hemisphere advantage for orthography and showed a left hemisphere advantage for phonology and assessment of possible semantic relationships. Taken together, the data support the idea that the right hemisphere uses orthography to make efficient decisions about novelty of an item, while the left engages in grapheme-to-phoneme conversion to test hypotheses about unfamiliar items. The convergence of data with previous research reveals that the procedure, as well as analyses of pseudowords, inform laterality research.

1. Introduction

The lexicon long has been suggested to include phonological, orthographic, and semantic information (e.g. Morton, 1969). Also long suggested is that the hemispheres have a different preferred strategy or strategies when invoking controlled processing to conduct an intentional search of the lexicon (Chiarello, 1985). However, laterality in the use of phonological, orthographic, and semantic strategies for intentional search is not always found in priming studies (for phonological processing, see Chiarello, 1985; Crossman & Polich, 1988). Moreover, when found, sometimes the findings are contradictory (for orthographic processing, see Chiarello, 1985; Crossman & Polich, 1988; for semantic processing, see Chiarello, 1985; Koivisto, 1997).

Priming studies that load controlled processing of lexical information encourage the conscious processing of a potential relationship between two lexical items (Collins, 1999; Neely, 1977). Two tasks, explicit judgement and lexical decision, are commonly used. Explicit judgement involves a conscious decision that a dimension of a phonological, orthographic, or semantic relationship does or does not exist between two words (Crossman & Polich, 1988; Khateb et al., 2000). Priming is evidenced by gains to speed and accuracy of response when there is a relationship compared to when there is not. Lexical decision investigates priming by presenting successive letter strings in which the preceding prime string either is or is not related to the succeeding target string on a dimension of phonology, orthography, or semantics (Chiarello, 1985; Peleg & Eviatar, 2009; Yochim, Kender, Abeare, Gustafson, & Whitman, 2005). Speed and accuracy of a decision that the target is a word is facilitated when there is a relationship, likely as a consequence of spread of activation from the prime to lexical representations that are associated (Collins & Loftus, 1975), whether the association is phonological, orthographic, or semantic. To encourage conscious processing of a relationship, participants are made aware of the predictive value of a prime by using primes that are perceptually clear, an SOA that is 500 ms or more, or by setting the probability of a relationship to be high (Collins, 1999; Neely, 1977). In turn, attention can be restricted to information in the lexicon expected by the priming context (Collins, 1999). Critical to the contention of probability of relationship is the operational definition of 'high'. Examples from laterality research include relatedness proportions of 25% (Collins, 1999), 30% (Chiarello, 1985), and 33% (Yochim et al., 2005) of the total stimulus set of words and nonwords in lexical decision, and 33% (Khateb et al., 2000) in explicit judgement.

In a seminal series of lexical decision experiments with normal subjects, Chiarello (1985) built on evidence derived from tests of commisurotomy patients and patients with unilateral damage to examine the possibility that the hemispheres may have different

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strategies in word recognition. Chiarello (1985) loaded processing for lexical decision to one or other hemisphere by presenting both prime and successive target to either the left visual field (LVF) or right visual field (RVF). An SOA of 600 ms, together with a manipulation of the prime–target relationship to be orthographically, phonologically, or semantically congruent, neutral, or incongruent tested whether controlled processing of congruent targets would show differential facilitation to response time and accuracy between the hemispheres. She found priming to word stimuli in both visual fields, suggesting that both hemispheres can use orthographic, phonological, and semantic cues to direct a search of the lexicon. However, priming was greater in the right hemisphere (RH) than left hemisphere (LH) to orthographic congruency, and in the LH than RH to semantic congruency, while there was no hemispheric difference to phonological congruency. She concluded that the hemispheres can institute a conscious search with any of the three strategies but the right prefers orthography while the left prefers semantics.

Further investigation of laterality of strategy use in controlled processing has been somewhat limited. Of those investigations, findings sometimes have supported those of Chiarello (1985) and other times have not.

Consistent with the contention that the hemispheres are similarly competent at using a phonological strategy (Chiarello, 1985), an explicit test of phonological processing showed similar error rates to a rhyme judgement of word pairs presented to the LVF or RVF, whether or not the pair was orthographically similar (Crossman & Polich, 1988). However, there was a trend toward a LH advantage. Moreover, an explicit task that measured speed of a rhyme judgement to lateralized word pairs that always were orthographically dissimilar (Khateb et al., 2000) found a significant LH advantage, suggesting that the LH may be better than the RH at processing phonology. In addition to a possible LH advantage for phonological processing, Crossman and Polich (1988) found a LH advantage for explicit judgement of visual similarity to word pairs that shared all but the first letter in common, suggesting that the LH also may be better than the RH at processing orthography. This stands in contrast to Chiarello's (1985) contention of a RH advantage for orthographic processing and, when taken together with their phonological findings suggest that the LH is better than the RH at detecting similarity, regardless of phonological or orthographic relatedness.

Chiarello's (1985) finding of bilateral priming to semantic associates has been replicated in several studies (Beeman et al., 1994; Burgess & Simpson, 1988; Faust & Mashal, 2007; Khateb et al., 2000; Koivisto, 1997; Mashal & Faust, 2008, 2009; Yochim et al., 2005); however, her finding of a LH advantage has not. Indeed, evidence has converged to suggest that laterality in priming to semantic associates depends on the type of semantic relationship between prime and target. A seminal study by Burgess and Simpson (1988) revealed that the timeline of activation of meanings of ambiguous words differs across the hemispheres. Their priming procedure presented an ambiguous word (e.g. bank) at fixation followed by a lateralized target for lexical decision. The target was related to the prime's dominant meaning (e.g. money), its subordinate meaning (e.g. river), or was not a word. At an SOA of 35 ms, they found priming to both dominant and subordinate meanings in the LH, but only to the dominant meaning in the RH. However, at an SOA of 750 ms, they found that the LH showed priming only to the dominant meaning, whereas the RH showed priming to both dominant and subordinate meanings. They suggested that the LH suppresses subordinate meanings over time, while the RH does not. Koivisto (1997) found converging evidence in a test where both primes and targets were lateralized, and primes were non-associated, but categorically related to the target. Priming occurred in the LH but not the RH to targets presented at a short SOA of 165 ms, and priming occurred in the RH but not the LH to targets presented at a long SOA of 750 ms after the prime. As primes were not directly related to the targets, Koivisto's evidence supports the idea that activation to distantly related information declines across time in the LH. He also concluded that the RH is slower to activate.

Beeman (1993) expanded the view when he found that people with RH damage are less accurate in making coherence inferences about stories than age-matched participants who are not brain damaged. He proposed a coarse/fine coding distinction in which the RH weakly activates broad semantic fields and the LH strongly activates the semantic associates most directly linked to local word context. Accordingly, laterality in semantic processing is predicted to depend on whether the task requires an inference among distant concepts (RH advantage) or locally relevant meaning (LH advantage). Consistent with these predictions, Beeman et al. (1994) found that at an SOA of 700 ms, accuracy of target naming was better in the LH when one of three prime words was directly related to the target than when all three primes were only distantly related to the target. In contrast, the RH was equally accurate to both conditions, suggesting the availability of a larger semantic field. The coarse/fine coding distinction also is supported by evidence revealing a RH advantage in a variety of tasks that tap into the conscious identification of a relationship among distant concepts, such as semantic judgements to novel metaphors (Faust & Mashal, 2007) and semantic judgements to novel two-word metaphoric expressions (Mashal & Faust, 2008).

In contrast to the assumption of the time course view (Burgess & Simpson, 1988) and the coarse/fine coding model (Beeman, 1993; Beeman et al., 1994) that asymmetry stems from activation at the semantic level, Peleg and Eviatar (2009) propose that semantic asymmetry stems from a lower level asymmetry in the timeline of activation of phonology. Their model for reading submits that semantic activation in the LH can proceed from either or both of orthography and phonology, and that when both are unambiguously related the LH receives a boost that enables quick access to meaning. In contrast, semantic activation in the RH proceeds from orthography, with activation of phonology only after related meanings are activated. To test the model, they measured lexical decision to lateralized targets presented only 150 ms after primes that were homographs. They found that homophonic homographs, which have only one pronunciation (e.g., bank) led to faster target processing in the LH than RH, as should occur if the LH receives a boost when the relationship between orthography and phonology is unambiguous. In contrast, they found that heterographic primes, which have more than one pronunciation (e.g. tear) led to faster target processing in the RH than LH as should occur if LH priming is hampered by competition between different phonological alternatives. Given that the SOA was too short to enable controlled processing, the asymmetries in semantic priming were concluded to result from a lower level asymmetry in the timeline of activation of phonology.

Previous research has used the divided visual field technique to investigate laterality of controlled processing, which though effective has some weaknesses. The divided visual field technique capitalizes on the anatomy of the visual system, which projects a lateralized stimulus to the contralateral hemisphere such that a RVF stimulus is projected to the LH and vice-versa. While relay across the hemispheres cannot be prevented in people with an intact corpus callosum, the assumption is that stimulus processing occurs primarily in the hemisphere that first received it (for theoretical and electrophysiological support, refer to Banich, 2003 and Coulson, Federmeier, Van Petten, & Kutas, 2005). Critical to the procedure is that the duration of the lateralized stimulus is brief. If longer than approximately 150 ms (although this will vary depending on the degree of lateralization), then there is risk that