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List constituency and orthographic and phonological processing: A shift to high familiarity words from low familiarity words

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ABSTRACT

Two lexical decision experiments build on established patterns of laterality and hemispheric interaction to test whether the presence of low familiarity words dynamically affects the use of an orthographic or phonological strategy for high familiarity words; and, if so, whether the hemispheres are similarly flexible in adapting to the constituency change. Experiment 1 restricted word strings to the highly familiar. Experiment 2 presented the same high familiarity words, along with an equal number of low familiarity words. Targets for lexical decision were presented at fixation to approximate normal viewing behaviour, either with or without a non-lexical distractor lateralized left visual field (LVF) or right visual field (RVF). Response time and accuracy were measured. Responses were faster in Experiment 1 than Experiment 2 to high familiarity words, pseudowords (orthographically correct), and non-words (orthographically incorrect), suggesting that a different strategy was used. A main effect of distractor location in Experiment 1 was due to more accurate responses to letter strings accompanied by a RVF distractor than no distractor, revealing a cost from hemispheric interaction compared to the right hemisphere when a task is simple. Experiment 2 found an interaction between distractor location and string type in both the response time and accuracy data. Separate analyses of word strings revealed a shift to a left hemisphere advantage: Accuracy to low familiarity words and speed to high familiarity words was better when accompanied by a LVF than a RVF distractor. Critical to a dynamic effect of list constituency is that the right hemisphere slowed to the same high familiarity words that had provoked speedier responses in Experiment 1. The findings are consistent with the use of an orthographic strategy in Experiment 1 and a phonological strategy in Experiment 2, and support the idea that right hemisphere access to familiar phonology is slower than the left hemisphere. Taken together, the findings suggest that the strategy used by both hemispheres is flexible, that both adapt to list constituency by adopting a strategy that is optimal for the task as a whole, and that there are different timelines of phonological activation in the two cerebral hemispheres.

1. Introduction

To date, investigations of laterality of lexical strategies for word recognition have presented different stimulus sets in tests of orthographic and phonological strategy use. Not yet tested is whether the use of these strategies by the brain's hemispheres is shifted for stimulus items that remain constant across different list constituencies. The current research manipulates list constituencies for lexical decision by restricting word strings to the highly familiar or including an equal number of low familiarity words, and uses established patterns of laterality and hemispheric interaction to infer the use of an orthographic or phonological strategy by each hemisphere. The goal is to assess whether the change in list constituency shifts the strategy for high familiarity words, and if so, whether the shift is present in one or both of the hemispheres. The findings test the flexibility with which the brain's hemispheres adapt to list constituency: Does one or both of the hemispheres maintain the use of a preferred orthographic or phonological strategy or shift to a less preferred strategy when it is likely to be optimal for word recognition?

To encourage processing by one or other hemisphere, visual tests of laterality and hemispheric interaction capitalise on the anatomy of the visual system which projects stimuli that are presented to the left or right of fixation to the hemisphere that is on the opposite side. Two procedures have capitalised on this contralateral projection. The traditional procedure presents the target to the left visual field (LVF) or right visual field (RVF) for a duration that is too brief to allow

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fixation (typically 250 ms or less). Although the procedure cannot prevent relay from one hemisphere to the other 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 et al., 2005). The procedure is the standard in the field. However, ecological validity has been challenged because visual acuity decreases with the distance from fixation and stimulus quality may be further compromised from brief presentation (Christman, 2001; Hughes and Rutherford, 2013; Luh and Levy, 1995).

More recently, a new procedure presents the target at fixation to mimic normal viewing behaviour. To weight processing of one or other hemisphere, the target is presented with a flashing, non-lexical distractor to the LVF or RVF. When no distractor is present, the test mimics the normal reading experience, and provides a measure of costs or gains relative to trials when the contribution of one or other hemisphere is impacted by a distractor. The logic of the procedure is based on three lines of evidence: First, the abrupt onset of a lateralized stimulus serves as an exogenous cue that reflexively orients attention to the cue from an attended location (Jonides, 1980; Müller and Rabbitt, 1989) and the orienting cannot be suppressed, regardless of frequency of distractor type or a secondary memory task (Jonides, 1981). Second, reflexive orienting is not symmetrical across the hemispheres, as revealed by ERP evidence showing independent activation of the contralateral hemisphere during early processing, even in the absence of eye movement (Yamaguchi et al., 1994). Third, findings from behavioural measures (Alvarez and Cavanagh, 2005) and functional near-infrared spectroscopy (Harasawa and Shioiri, 2011) show that more objects can be tracked if some are presented to the LVF and others to the RVF than if all are presented to one hemisphere, suggesting the hemispheres have independent attentional resources. These lines of evidence converge to predict that a fixated target accompanied by a LVF distractor will weight target processing to the left hemisphere (LH), because the distractor competes for the attention of the right hemisphere (RH), and vice versa for a RVF distractor. Lexical decision research supports the predictions. Responses have been found to be faster (Rutherford and Lutz, 2004; Rutherford, 2006) and more accurate (Rutherford, 2006) to a fixated word target accompanied by a LVF distractor than a RVF distractor, supporting the established LH advantage for word processing. Moreover, phonological dyslexics (Rutherford, 2006) showed a shift from a LH advantage to familiar words to a RH advantage to fixated pseudowords, consistent with impaired grapheme-to-phoneme conversion in the LH in phonological dyslexics (Bloch and Zaidel, 1996), and provided evidence that a distractor exerts an effect whether in the LVF or RVF. A series of priming studies (Rutherford and Mathesius, 2012) revealed a LH advantage for processing phonology and a RH advantage for processing both orthography and a broad field of semantic associates, just as have been found with the traditional procedure (Beeman, 1993; Beeman et al., 1994; Bloch and Zaidel, 1996; Burgess and Simpson, 1988; Chiarello, 1985; Koivisto, 1997; Lavidor and Ellis, 2003).

The new procedure, and the traditional procedure, have been used in conjunction with a priming paradigm to show that list constituency does impact performance in a lexical decision task: A target that is related to the prior prime stimulus will provoke faster and more accurate responses than a target that is not related, and the performance benefit typically holds whether the relationship is orthographic, phonological, or semantic, likely as a consequence of the spread of activation from the prime to associated entries in the mental lexicon (Collins and Loftus, 1975), and to a process that occurs either automatically or with intentional control (Neely, 1977, 1991). Critical to the current test of list constituency is evidence suggesting that the hemispheres differ in their preference for using an orthographic or phonological strategy.

A RH preference for orthographic processing is revealed by tests in which a target shares common letters in common positions in a common letter case with a preceding prime. The commonalities facilitate recognition by global shape if the target is a familiar entry in the mental lexicon. Traditional lateralized presentation has shown facilitation in both hemispheres; however, facilitation is greater to targets in the LVF than RVF in lexical decision to words (Chiarello, 1985; Lavidor and Ellis, 2003) and in repetition priming of a word-stem completion task (Marsolek et al., 1992, 1994), suggesting that the RH prefers orthographic processing. The new procedure also found facilitation in both hemispheres; however, performance to unprimed word strings was faster and more accurate to targets presented with a distractor to the RVF (RH processing of the target) than the LVF (LH processing of the target) (Rutherford and Mathesius, 2012), suggesting the RH has better baseline processing of orthography.

A LH preference for phonological processing is revealed by tests in which a target rhymes with a preceding prime. Traditional lateralized presentation has found faciliation in both hemispheres when the priming relationship was consciously processed; however, facilitation was greater to targets in the RVF than LVF in lexical decision to words whether the relationship was or was not consciously processed (Chiarello, 1985; Lavidor and Ellis, 2003), suggesting that the LH prefers phonological processing. The new procedure also found facilitation in both hemispheres to primed word targets that were consciously processed, but found facilitation to pseudoword targets only when accompanied by LVF distractor (LH processing of the target) but not a RVF distractor (RH processing of the target) (Rutherford and Mathesius, 2012). The lack of facilitation to pseudoword targets with a RVF distractor converges with a long history of evidence from tests of split brain patients (Zaidel and Peters, 1981) and dyslexics (Coltheart, 1983; Rutherford, 2006; Schweiger et al., 1989) suggesting that only the LH has the ability to sequentially convert graphemes to phonemes in order to sound out an unfamiliar letter string.

While the LH advantage in lexical decision is well established, a consensus view is that the RH also contributes to lexical processing (Peleg and Eviatar, 2008). If both hemispheres are involved, then a question that follows is whether two hemispheres are better than one. Perhaps surprisingly, this is not always the case. A common paradigm measures performance in a matching task in which a target is presented to either the LVF or RVF for a match to one of several stimuli that are located so that some are in the LVF and others in the RVF. Evidence from lexical displays (Banich and Belger, 1990; Belger and Banich, 1992, 1998) and pictures (Compton, 2002; Koivisto, 2000) usually find that a match to a physically identical target is better performed when both stimuli are presented to the same hemisphere. In contrast, a match of target that must be transformed (e.g. A and a) is usually better performed when the target and its match are presented to opposite hemispheres. The findings support the contention that the integration of information across the hemispheres is computationally demanding, with the consequence that the cost of integration outweighs the gain from the additional processing power of both hemispheres when a task is simple, and the gain outweighs the cost when a task is difficult (Belger and Banich, 1998). However, there is an exception when a difficult task is strongly lateralized.

Matching tasks that required the conversion of graphemes to phonemes to identify a rhyming relationship between a target and probe (e.g. G and sea) (Belger and Banich, 1998) or “AU” or “EAU” to match the sound /o/ in French (Tremblay et al., 2009) did not benefit from hemispheric interaction compared to the LH alone, as was predicted from evidence suggesting that only the LH can perform the conversion (Rayman and Zaidel, 1991). Moreover, a lexical decision task that presented a target to the LVF or RVF either by itself (unilateral trial) or with a lexical distractor to the opposite visual field (bilateral trial) found a benefit from hemispheric interaction compared to the LH alone in English and Hebrew readers, but not in Arabic