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Responses on a lateralized lexical decision task relate to both reading times and comprehension

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ABSTRACT

Research over the last few years has shown that the dominance of the left hemisphere in language processing is less complete than previously thought [Beeman, M. (1993). Semantic processing in the right hemisphere may contribute to drawing inferences from discourse. *Brain and Language, 44*, 80–120; Faust, M., & Chiarello, C. (1998). Sentence context and lexical ambiguity resolution by the two hemispheres. *Neuropsychologia, 36*(9), 827–835; Weems, S. A., & Zaidel, E. (2004). The relationship between reading ability and lateralized lexical decision. *Brain and Cognition, 55*(3), 507–515]. Engaging the right brain in language processing is required for processing speaker/writer intention, particularly in those subtle interpretive processes that help in deciphering humor, irony, and emotional inference. In two experiments employing a divided field or lateralized lexical decision task (LLDT), accuracy and reaction times (RTs) were related to reading times and comprehension on sentence reading. Differences seen in RTs and error rates by visual fields were found to relate to performance. Smaller differences in performance between fields tended to be related to better performance on the LLDT in both experiments and, in Experiment 1, to reading measures. Readers who can exploit both hemispheres for language processing equally appear to be at an advantage in lexical access and possibly also in reading performance.

As individuals learn to read, differences in ability arise that relate to inequalities of cognition and experience. These differences are found mainly in the higher level cognitive processes required for full comprehension, but also in those lower level processes such as word recognition that are assumed to become increasingly automatic as reading becomes more practiced. Effective recruitment of all available resources is likely to be the hallmark of a skilled reader, and this includes engaging both hemispheres of the brain.

Since the work of Marc Dax and Paul Broca in the mid-19th century it has been known that the left hemisphere has a critical role in language processing (Cubelli & Montagna, 1994). In contrast, the role of the right hemisphere has become apparent only comparatively recently. Damage to the right hemisphere (RHD), arising from neurological insult such as stroke, frequently results in deficits at the discourse level in interpreting inference, context, as well as broad themes and concepts (Beeman, 1993; Myers & Brookeshire, 1996). RHD is associated with inappropriate use of inference and the inability to make use of contextual information (Bryan, 1988), as well as difficulty in recognizing appropriate use of inference (Schneiderman, Murasugi, Saddy, 1992).[1] At its most extreme, failure to engage the right hemisphere in language processing may be related to psychoses, specifically those relating to schizophrenic disorders (Mitchell & Crow, 2005).

In the non-patient population, readers who comprehend well may be more fully engaging the right hemisphere in processing text in order to maximize their understanding and resolve textual ambiguity (Faust & Chiarello, 1998). The right middle temporal region in particular seems to be implicated in establishing and maintaining global coherence in discourse (St. George, Kutas, Martinez, & Sereno, 1999). Walczyk, Marsiglia, Johns, and Bryan (2004) suggest that good slow readers have learned to do more consciously what good fast readers do more or less automatically; thus they require longer reading times, specifically more rereading, to reach a similar interpretation. This may imply more conscious activation of right brain resources.

As children learn to read, word recognition becomes increasingly automatic and the relative contribution of efficient lexical access to overall comprehension declines (Yuill & Oakhill, 1991). However, as reading skills develop, the semantic route to word recognition, which relies in large part on contextual clues, becomes increasingly important to understanding less familiar words (Cain, Oakhill, & Lemmon, 2004; Nash & Snowling, 2006). Consequently, differences may arise between skilled and less able readers in their ability to recognize words, particularly less frequent words and irregular or exception words that are not rule-based. Effective reading comprehension in normal adult readers still depends on

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[1] Specifically RHD patients are unable to make use of thematic information.

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efficiency in low level processes such as lexical access (Samuels & Naslund, 1994; Swinney, 1979).

Studies into the sources of individual difference in reading using the lexical decision task (LDT) have found that skilled readers are both faster and more accurate in identifying low frequency words (Lewellen, Goldinger, Pisoni, & Greene, 1993; Schilling, Rayner, & Chumbley, 1998) and that students who are infrequent readers tend to be slower and less efficient in all components of the task, (Chateau & Jared, 2000; Lewellen et al., 1993). Scores on the LDT in normal adult readers have been found to correlate significantly with both reading comprehension, and to a lesser extent with reading span, (Dixon, LeFevre, & Twilley, 1988). Scores also correlate with dual task performance when the task involved both naming and probe-detection (Herdman & LeFevre, 1992); decrements in performance on the dual task, compared with the tasks performed separately, were predicted by scores on both the LDT and a measure of working memory (WM). While accuracy and response time (RT) provide evidence for different types of processing, especially for non-words, accuracy and RT by hemispheres may also be informative, as these have also been shown to be correlated with both reading comprehension (Weems & Zaidel, 2004) and reading times (Schilling et al., 1998).

Recently Weems and Zaidel (2004) used a divided visual field version of the LDT, or lateralized LDT (LLDT), in which stimuli are presented to either the participant's left (LVF) or right visual field (RVF); RTs and error rates by visual fields were found to be correlated with a measure of reading comprehension and vocabulary. Accuracy in response to words was positively related to scores on the Nelson Denny reading task, while RTs to non-words in both visual fields was related to both vocabulary and reading comprehension. Using the LLDT allows exploration of differences by visual field and thus, indirectly, differences in hemispheric processing, as information perceived in one visual field is initially processed in the contralateral hemisphere. More pronounced lateralization of the processes required to understand language could be an important factor in the difference between readers of different levels of ability. If this is the case, processes such as textual integration required for local coherence over a few words, in which any ambiguity is rapidly resolved, and those required for global coherence, making sense of longer sections of text, which rely on the left and right hemispheres respectively, will occur primarily in the appropriate hemisphere. Alternatively, it may be that the important issue is the involvement of, and cooperation between, the hemispheres. Brysbaert (1994, 2004), on the basis of an increased word-beginning superiority effect for subjects with left rather than right hemispheric dominance, suggests that interhemispheric transfer is essential to word recognition in many instances.

More pronounced hemispheric differences or inferior interhemispheric communication may partly account for the problems poor comprehenders have accessing recent information and suppressing irrelevant information (Gernsbacher, Varner, & Faust, 1990). Recent work (Long & Chong, 2001) suggests problems may be less of access than of integration. Able readers may be more effective in recruiting their right hemisphere and may have less pronounced lateralization of the processes involved in language processing. In particular, if the right hemisphere has an important role in discourse processing, as suggested by problems RHD patients have in using inference (Beeman, 1993), it may allow able readers to maintain alternate meanings, especially in situations where there is ambiguity, as demonstrated by differential priming in the two hemispheres (Beeman, 1998; Faust & Chiarello, 1998), and more active error monitoring (Iacoboni, Rayman, & Zaidel, 1997). While the left-brain makes greater use of phonology (Pugh et al., 1996) and is generally quicker and more accurate in word recognition, particularly for rule-based words, the right hemisphere is thought to be involved in more top–down processing and to make greater use of orthographic and semantic information. Beeman (1998) suggested that, while the left hemisphere deals in close semantic associations, the right hemisphere employs coarser more distant semantic relations, a suggestion supported by work on metaphors (Schmidt, DeBuse, & Seger, 2007), which showed a right hemisphere advantage for unfamiliar but not familiar metaphors.

Symmetry in language processing has been related to improved verbal recall (Catani et al., 2007) and therefore could be related to enhanced reading comprehension. In a study using fMRI, Meyler et al. (2007) compared brain activation for more and less able readers in a sentence comprehension task. Although the pattern of activation differed between hemispheres, overall activation in both hemispheres was greater for the more able readers. Hirnstein, Hausmann, and Güntürkün (2008) used a visual half field procedure to test symmetry of processing between the two visual fields. Subjects in the more symmetrical group had faster RTs and were more accurate in their responses in a word/non-word discrimination task than those in the more asymmetric group. Thus hemispheric differences in language processing are potentially of interest. A study of mathematically gifted middle-school boys found they did not show the hemispheric differences seen in less gifted students, when performing a task that required either local or global matching (Singh & O'Boyle, 2004) "suggesting more interactive, cooperative left and right brains".

Therefore, it may be hypothesized that readers who comprehend well are more fully or more equally engaging their right hemisphere in language processing, particularly in later processes of integration and interpretation, and they will be found to have similar levels of activation for language processes in both hemispheres. Rapid and accurate responses by readers on LVF (right hemisphere) presentation of an LLDT will tend to be correlated with good (late) comprehension, in particular when this requires the use of inference or integrating context. Rapid and accurate responses following RVF presentation of the same task are more likely to correspond with good early, more literal processing by readers. However, it should be noted that responses following presentation in one field are likely to be strongly correlated with those in the other visual field. A specific prediction can be made that those readers who are recruiting both hemispheres effectively and show minimal differences by visual field in the LLDT, will perform better overall on the task, and generally require less rereading of difficult sentences, and thus they will tend to have shorter total reading times and possibly improved comprehension. Although some recent findings provide support for the long held belief in differences in brain lateralization of language between the sexes (Catani et al., 2007; Clements et al., 2006; Hill, Ott, Herbert, & Weisbrod, 2006), meta-analyses have not shown significant differences by gender (Sommer, Aleman, Bouma, & Kahn, 2004; Wallentin, 2009), and none were anticipated in this study.

Two studies were performed in each of which participants were asked to complete a reading task and the LLDT, as well as other tests of cognitive ability and reading experience. The reading task in Experiment 1 required participants to read locally ambiguous sentences and answer comprehension questions to test their understanding. In Experiment 2, similar target sentences were preceded by two sentences which provided context for the reader's interpretation. In this paper the focus is on the relationships found between results on the LLDT and responses and times on the reading task.

1. Experiment 1

In the first experiment sentence reading and comprehension were tested using target sentences containing a fronted adjunct ambiguity (see (1) and (2) below) that causes readers to reconsider their initial analysis of the sentence, followed by other measures of cognitive processing and reading experience, as well as a filler