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Short Communication

Evidence for right hemisphere phonology in a backward masking task

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ABSTRACT

The extent to which orthographic and phonological processes are available during the initial moments of word recognition within each hemisphere is under specified, particularly for the right hemisphere. Few studies have investigated whether each hemisphere uses orthography and phonology under constraints that restrict the viewing time of words and reduce overt phonological demands. The current study used backward masking in the divided visual field paradigm to explore hemisphere differences in the availability of orthographic and phonological word recognition processes. A 20 ms and 60 ms SOA were used to track the time course of how these processes develop during pre-lexical moments of word recognition. Nonword masks varied in similarity to the target words such that there were four types: orthographically and phonologically similar, orthographically but not phonologically similar, phonologically but not orthographically similar and unrelated. The results showed the left hemisphere has access to both orthography and phonology early in the word recognition process. With more time to process the stimulus, the left hemisphere is able to use phonology which benefits word recognition to a larger extent than orthography. The right hemisphere also demonstrates access to both orthography and phonology in the initial moments of word recognition, however, orthographic similarity improves word recognition to a greater extent than phonological similarity.

1. Introduction

Research on the right hemisphere's reading and language abilities has established the right hemisphere as a processing system that is distinct and separate from the left. It does not simply echo the processes of the left hemisphere. The early work with commissurotomy patients revealed its extensive comprehension of auditory language, restricted reading ability and with only few exceptions, lack of speech (Zaidel, 1998). With time, the collection of behavioral studies using the divided visual field technique with normal participants revealed finer differences in how each hemisphere processes linguistic information. For example, the right hemisphere has been shown to preserve lower-level visual characteristics of words (i.e. case) or letter identities during visual word recognition whereas the left hemisphere extracts more abstract and lexically-based representations very quickly (see Chiarello (2003) for a review). Similarly, the right hemisphere seems to maintain the more distantly related meanings of words compared to the left hemisphere which quickly selects the most appropriate meaning for the context and discards superfluous meanings (see Chiarello (2003) for a review). These differences in semantic processes have been demonstrated across categorically related words, ambiguous words and their various meanings and even in cases where sentence contexts have served as primes.

While the role of the right hemisphere has been fairly well specified in behavioral semantic tasks, its role during initial moments of word recognition remains under specified. It seems evident that the cerebral hemispheres access orthography and phonology to different degrees, however, the extent to which each hemisphere uses these types of information is vague in the literature. Studies using tasks such as rhyme judgment (e.g. participants indicate whether two words rhyme or do not rhyme) find a left hemisphere advantage for detecting when two words rhyme, suggesting left hemisphere specialization for phonological processes (Crossman & Polich, 1988; Khateb et al., 2000). An interesting finding in these studies shadows the simple conclusions one could draw from these results. The right hemisphere can detect non-rhyming trials more accurately than the left hemisphere. This result has been replicated in a visual match task (e.g. participants indicate whether two words look similar or not) (Crossman & Polich, 1988) and a semantic category match task (e.g. participants indicate whether two words are in the same category or not) (Khateb et al., 2000), suggesting a decision-making bias across the hemispheres that is independent of the type of similarity being judged. Thus, tasks that require explicit judgment may not be the best paradigm to measure the pre-lexical availability of phonological or orthographic processes within a hemisphere as they could be overshadowed by differences between the hemispheres that arise later during the decision making stage of these tasks.

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When tasks do not require explicit phonological decisions like rhyme judgment, right hemisphere sensitivity to phonological characteristics of the stimulus is observed (Barry, 1981; Chiarello, Hasbrooke, & Maxfield, 1999; Lukatela, Carello, Savic, & Turvey, 1986; Smolka & Eviatar, 2006). Chiarello et al. (1999) showed that in a naming task, phonologically similar distractors facilitated naming performance of target words equivalently in both visual fields. Barry (1981) found a significant pseudohomophone effect in a lexical decision task (i.e. worse rejection performance for nonwords that are phonologically identical to real words compared to those that are not) in both visual fields. Lukatela et al. (1986) showed that when words were phonologically ambiguous (i.e. could have more than one phonological representation) in Serbo-Croatian, lexical decisions in both visual fields were worse compared to unambiguous words. More recently, Smolka and Eviatar (2006) showed that when Hebrew words were pointed incorrectly to distort phonological representations, this created interference distortion in a naming task in both visual fields. These results demonstrate that the right hemisphere must possess some level of phonological processing ability, otherwise, these effects would be absent in left visual field performance.

While these studies have gotten us closer to understanding the right hemisphere's capabilities during reading, the time course of the availability of phonology is still unknown. Because the studies mentioned above did not restrict viewing time or manipulate stimulus onset asynchronies (SOAs), it is still unknown whether the right hemisphere has direct access to phonology and computes it on its own, or if sound information is provided to the right hemisphere via callosal relay after it is computed by the left (Zaidel, Clarke, & Suyenobu, 1990). By combining short stimulus durations and visual masking, the time a reader has to process stimuli can be restricted to a period of decoding that is more likely to reflect the earliest availability of orthography and phonology in each hemisphere.

Few studies have combined short duration and visual masking with the divided visual field paradigm. Lavidor and Ellis (2003) used a masked priming paradigm in which the primes varied in orthographic and phonological similarity to the target word. Their results revealed orthographic and phonological priming in the left hemisphere, but only orthographic priming in the right hemisphere. In fact, there was greater orthographic priming in the right hemisphere compared to the left suggesting the possibility for superior orthographic processing in the right hemisphere. These findings suggest that during initial word processing, phonology is not the primary pre-lexical process in the right hemisphere.

Varying SOAs in behavioral priming tasks can provide information on how orthographic and phonological processes unfold over time in a way similar to the time course differences seen in the semantic literature (see Chiarello (1998, 2003) for a review). Halderman and Chiarello (2005) used lateralized backward masking with SOAs of 30 ms and 50 ms to track the time course of orthographic and phonological processes in each visual field. Nonword masks were orthographically and phonologically similar, orthographically similar with little phonological similarity or unrelated to the target word. Participants selected the target word in a two-alternative forced choice decision. The results showed that orthography and phonology were available early in the left hemisphere and that when phonological similarity was present, word identification was better than just orthographic similarity alone. Conversely, there was no evidence that phonology affected word identification in the right hemisphere. However, orthographic similarity alone improved target identification more in the right hemisphere compared to the left suggesting enhanced pre-lexical orthographic processing in the right hemisphere.

Across these behavioral studies, it appears that phonological processing is a dominant feature of left hemisphere reading from the earliest moments of word recognition and onward. Conversely, initial reading processes in the right hemisphere seem to be governed by orthographic processes. While the right hemisphere has shown sensitivity to phonological characteristics of print, this has not been demonstrated pre-lexically. There were a few limitations to previous studies that leave this question unanswered. First, Halderman and Chiarello (2005) did not reveal any interactions with SOA which was treated as a between subject variable. Individual differences in visual masking may have weakened the possibility of finding time course differences in this study. Second, neither Lavidor and Ellis (2003) nor Halderman and Chiarello (2005) had a condition in which phonology was the sole source of similarity. Therefore, the current study used a lateralized backward masking paradigm similar to the one reported in Halderman and Chiarello (2005). Here, the target and nonword masks were presented for either 20 ms each or 60 ms each, with SOA as a within subject variable. In addition, the current study includes four types of target/mask similarity: orthographically and phonologically similar (O+P+), orthographically similar with little phonological similarity (O+P−), phonologically similar with little orthographic similarity (O−P+) and unrelated (O−P−). Including a condition where phonology is the main source of similarity (O−P+) provides a more stringent test of the right hemisphere's ability to access phonological information about print. If target identification is faster or more accurate with phonological similarity alone (O−P+) relative to the unrelated condition (O−P−), this would be evidence that some ability to process phonology exists in the right hemisphere. If the right hemisphere is not capable of processing phonology, the condition where phonology is the only source of similarity (O−P+) should be equivalent to the unrelated condition (O−P−).

2. Results

A 2 (SOA; 20 ms and 60 ms) × 4 (Mask Type; O+P+, O+P−, O−P+, and O−P−) × 2 (Visual Field) repeated measures ANOVA was conducted with percent correct and the logged reaction time of correct trials as the dependent variables. Reaction times of less than 350 ms (indicating spurious responses) and those that exceeded the subjects' conditional means ±2.5 standard deviations were deleted which amounted to .01% of the total correct trials. Reaction times were then log transformed because they were not normally distributed. The Greenhouse–Geisser correction was applied to *p*-values on *F*-tests with more than two levels.

2.1. Percent correct

For percent correct (see Table 1), there was a main effect of SOA ($F(1,46) = 29.32$, $p < .001$, $\eta_p^2 = .389$). A main effect of visual field showed responses were more accurate to RVF presentations than LVF presentations ($F(1,46) = 81.02$, $p < .001$, $\eta_p^2 = .638$). There was also a significant main effect of Mask Type ($F(3,138) = 151.19$, $p < .001$, $\varepsilon = .934$, $\eta_p^2 = .767$). Responses were most accurate for the O+P+ and O+P− conditions which were both more accurate than the O+P− condition. Responses in the O−P− were less accurate compared to all other mask type conditions.

Table 1
Percent correct means and standard deviations.

20 ms SOA	O+P+	O+P−	O−P+	O−P−
LVF	71.6 (10.9)	73.3 (11.0)	63.2 (11.4)	55.3 (11.4)
RVF	78.2 (10.8)	76.8 (11.8)	71.7 (10.2)	61.8 (13.3)
60 ms SOA				
LVF	80.0 (12.2)	79.5 (11.4)	75.1 (11.8)	54.0 (13.6)
RVF	85.4 (10.6)	83.6 (8.2)	79.6 (10.4)	62.4 (13.4)