The Effects of Hemispheric Specialisation and Spatial Cueing on Orthographic and Phonological Processing in Word Recognition Tasks.

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Abstract

Within the framework of the dual route model of word recognition, this experiment investigated the role of spatial attention and hemispheric specialisation in word recognition. Within a 2 (task: orthographic, phonological) x 2 (cue: valid, invalid) x 2 (visual field: left, right) repeated measures design, 28 University of Tasmania students responded to lexical and phonological decision tasks presented on a computer. Analysed data showed support for the hypothesis that orthographic processing would be faster than phonological processing. The second hypothesis, that validly cued stimuli would be responded to faster than invalidly cued stimuli, was also upheld, as was the hypothesis that right visual field presentation of stimuli would result in faster response times than left visual field presentation. The prediction of a task x visual field interaction was not supported; however a significant cue x visual field interaction was found indicating that the valid cue advantage was restricted to the LVF. It was concluded that while evidence provided some support for a dual-route model of word recognition, further research could provide a more complete understanding of a right visual field advantage and the role of spatial attention in word recognition tasks.

Introduction

The dual-route model of reading contends that there are separate pathways for word recognition; the lexical pathway involving orthographic processes allowing quick access to the mental lexicon, and the non-lexical pathway involving serial, phonological processing of letters which is slower (Coltheart, Curtis, Atkins, & Haller, 1993). Studies concerning spatial attention in word recognition support this model. Using a cueing paradigm, Auclair and Sieroff (2002) found that phonological processes required more focused attention and took longer than orthographic processes.

Visual information pathways are located in each hemisphere of the brain; the right dorsal, likely to involve the attentional resources required for phonological processing, and the left ventral stream associated with object recognition and likely to be associated with orthographic processing (Ungerleider & Mishkin, 1982; Livingstone & Hubel, 1988; Zeki, 1993; Merigan & Maunsell, 1993; Logothetis & Sheinberg, 1996, cited in Vidyasager & Pammer, 1999). In view of this physiology, it is argued that evidenced advantages in right visual field (RVF) presentation of lexical decision targets is explained by specialisation of the language centre in the brain's left hemisphere and the opposite visual field associations (Iacoboni & Zaidel, 1996). However, the involvement of a RVF advantage with right hemisphere presentation becomes less distinct. Iacoboni and Zaidel (1996: 121) posit a " callosal relay model" that explains a decrease in the RVF advantage when information that cannot be processed in the right hemisphere is conveyed through the corpus callosum, to the left hemisphere for processing. Such an approach is supported by the findings of Weekes, Capetillo-Cunliffe, Rayman, Iacoboni, and Zaidel (1999), who argue that while lexical pathways exist in both hemispheres, a non-lexical or phonological pathway only occurs in the left hemisphere, and furthermore the pathways do not interact either within, or between hemispheres.

This structural account of the dual route approach is not without its challengers. Iacoboni and Zaidel (1996) cite evidence to support the notion that hemispheric interaction is involved in word recognition processes, while other researchers argue that a RVF advantage can be attributed to the differing capacity of both hemispheres to process orthographic and phonological information (Geffen, Bradshaw, & Wallace, 1971; Ross, 1985; Allen, 1983, cited in Nicholls & Wood, 1988). Likewise, Weekes et al. (1999) argue that each hemisphere can be involved in both lexical and phonological processing, however this is moderated by individual differences and word variables such as length and frequency.

The principal aim of this study was to explore more fully spatial attention, hemispheric specialisation, and the proposed pathways of the dual-route model of word recognition. This was achieved by comparing response times to lexical decision tasks involving phonological and orthographic processing. Accordingly, it was hypothesised that orthographic tasks would be responded to faster than phonological tasks, valid cues would result in faster response times than invalid cues, and RVF presentation of stimuli would produce faster response times than left visual field (LVF) presentation. It was also predicted that, given a structural approach to understanding word recognition, there would be a task x visual field interaction, in that, while orthographic tasks would have a faster response time than phonological tasks for presentation in both visual fields, LVF presentation would result in a considerably slower response to phonological tasks.

Method

Participants

The experiment sample consisted of 28 University of Tasmania students recruited by the experimenters. Three data sets were excluded since participant's ages were outside the specified range of 18 to 25 years. The remaining sample comprised 18 female and seven male participants, with all reporting normal or corrected-to-normal vision and English as their first language.

Materials

The experiment was conducted on a PC computer with participants responses made on a keyboard. A lexical decision task program was used to measure response time to a phonological task and an orthographic task developed from the ARC Nonword Database (Rastle, Harrington, & Coltheart, 2002). Task 1 (Phonological) consisted of 124 trials of equally represented pseudohomophones and nonwords, while Task 2 (Orthographic) comprised 124 equally represented words and nonwords. Pseudohomophones are letter strings that sound like real words when pronounced aloud (e.g. brane sounds like brain), while nonwords are pronounceable letter strings that do not sound like real words (e.g. brixt). Each task consisted of equally represented and matched four, five, or six-letter letter-strings, employed orthographically legal nonwords, and matched words for frequency. All were presented in a regular, size 28 Times New Roman font type. Participants were given information sheets and required to indicate their consent by signing appropriate forms.

Procedure

Participants were required to complete two tasks for this experiment, however a further two tasks of similar length and format were also completed as part of a larger study. In addition to time taken for instruction and short rest periods, each task took approximately seven minutes to complete, resulting in a total participation time that approached 40 minutes. In each case participants were directed to respond to 124 presentations of letter-strings which were displayed either side of a central fixation point on a computer screen, following a valid or invalid attentional cue (arrow pointing left or right). In Task 1 (Phonological), to examine the phonological pathway proposed in the dual route model of reading, participants were shown a series of pseudohomophones and nonwords. They were instructed to consider each presentation of letter-strings and decide if it sounded like a real word and respond by pressing the z key if yes, or ? key if no. The aim of Task 2 (Orthographic) was to explore the lexical pathway of the dual route model and accordingly participants were asked to consider if each of the presented letter-strings were words and respond in a similar fashion to Task 1. Tasks were counterbalanced with each presentation having a stimulus duration of 2000 ms, a cue duration of 200 ms, an interval between each trial of 500 ms, and a 500 ms interval between cue and stimulus.

Design and Data Analysis

The study was a 2 (visual field: left, right) x 2 (cue: valid, invalid) x 2 (task: phonological, orthographic) repeated measures design. The dependent variable in each case was response time for correct responses. Data were analysed using a three-way repeated measures ANOVA and an alpha level set at 0.05. Separate one-way, repeated measures ANOVAs with Bonferroni adjusted alpha were used to analyse the significant interaction.

Results

The resultant data were collated with means and standard deviations calculated for correct responses for each task and are illustrated in Table 1. In all instances mean response times to orthographic stimuli were faster than phonological stimuli, while mean response times to validly cued stimuli were, in the main, faster than invalidly cued stimuli. Similarly, most RVF presentations resulted in faster mean response times.

Task	Valid Cue (N=25)				Invalid cue (N=25)			
	Right Visual Field		Left Visual Field		Right Visual Field		Left Visual Field	
	M	SD	M	SD	M	SD	M	SD
Phonological	1199.9	289.8	1198.0	255.7	1193.9	226.5	1265.5	277.0
Orthographic	754.6	145.1	755.4	133.6	766.6	156.1	834.4	120.9

Table 1: *Means and standard deviations for correct response times to phonological and orthographic tasks presented in validly and invalidly cued right and left visual fields.*

Means were compared using a 2 (visual field: left, right) x 2 (cue: valid, invalid) x 2 (task: phonological, orthographic) repeated measures ANOVA . This revealed a significant main effect of task, $F(1, 24) = 131.92$, $p < 0.001$, indicating that orthographic stimuli were responded to significantly faster than phonological stimuli. A significant main effect of cue was also found, $F(1,24) = 16.99$, $p < 0.001$, with response times to validly cued stimuli significantly faster than invalidly cued stimuli. Similarly, a significant main effect of visual field was evident, $F(1,24) = 7.70$, $p < 0.05$, showing that response times for stimuli presented in the RVF were significantly faster than those presented in the LVF. However, the significant main effects of cue and visual field were modified by a significant cue x visual field interaction, $F(1,24) = 7.08$, $p < 0.05$ (see Figure 1). The task x cue x visual field interaction was not significant, $F(1,24) = 0.01$, $p = 0.91$, and neither were the task x cue interaction $F(1,24) = 1.39$, $p = 0.25$, nor the task x visual field interaction $F(1,24) = 0.001$, $p = 0.98$.

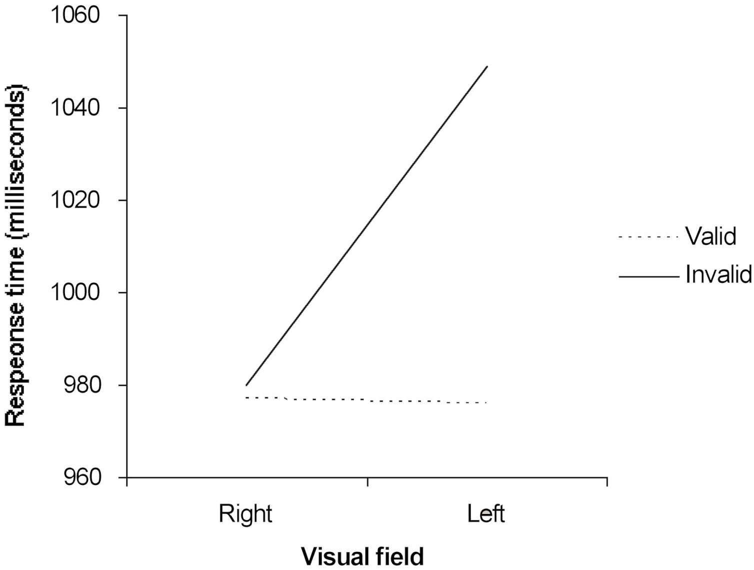

Figure 1. *Mean correct response times for validly and invalidly cued targets presented in right and left visual fields.*

The significant cue x visual field interaction was further analysed using repeated measures ANOVAs and a Bonferroni adjusted alpha. As can be seen in Figure 1, response times for validly cued stimuli presented in the RVF and LVF were not significantly different, $F(1,24) = 0.001$, $p = .974$. However, response times for invalidly cued stimuli presented in the RVF were significantly faster than invalidly cued stimuli presented in the LVF, $F(1,24) = 10.95$, $p < 0.0125$. It was also found that for stimuli presented in the RVF, response times for those validly cued were not significantly different from those invalidly cued, $F(1, 24) = 0.04$, $p = 0.84$. Response times for stimuli presented in the LVF were significantly faster for validly cued stimuli than invalidly cued stimuli, $F(1,24) = 17.99$, $p < 0.0125$.

Discussion

The results of the study supported the initial three hypotheses, in that orthographic processing was significantly faster than phonological processing, validly cued stimuli were overall responded to significantly faster than invalidly cued stimuli, and stimuli presented in the RVF were responded to significantly faster than LVF presentation overall. The significant main effect of task provided some support for the findings of Auclair and Sieroff (2002), and Coltheart et al.'s (1993) dual route model of word recognition.

In view of past research and the structural approach put forward by Weekes et al. (1996), it seems reasonable to presume that response time to orthographic and phonological tasks would not be uniform across visual fields. Lack of support for this prediction may be explained in terms of criticisms of this approach, however, it also may indicate that, in fact, each hemisphere is involved in both lexical and phonological processing, as argued by Iacoboni and Zaidel (1996). Furthermore, methodological issues should not be overlooked. Handedness was not controlled for in this study and given that responses were made using both left and right hands, it is not unreasonable to expect response times to be differentially influenced by the favoured hands of the participants. In addition, and perhaps more importantly, supplementary data was gathered at the time the experiment was conducted. This essentially doubled the length of the procedure, which may have been tiring and confusing for the participants and may well have influenced response times.

The finding of a significant cue x visual field interaction however impacts upon the interpretation of the main effects of cueing and visual field. This interaction indicated that validly cued stimuli were responded to significantly faster than invalidly cued stimuli in the LVF, while there was no significant difference between validly and invalidly cued stimuli in the RVF. Further, invalidly cued stimuli were responded to significantly faster when presented in the RVF than in the LVF, while there was no significant difference in response times between RVF and LVF validly cued presentation of stimuli. This outcome is a contradiction to the structural explanation of the processes of word recognition where invalidly cued RVF presentation (corresponding to LVF attention) would result in a slower response time than invalidly cued LVF presentation (corresponding to RVF attention). While again methodological issues should be considered, the emergence of a RVF advantage in invalidly cued trials raises some questions regarding the role of spatial attention and visual pathways in word recognition processes and suggests a more complex interplay of attentional resources in both hemispheres.

An understanding of how words are recognised has practical implications across a number of areas. Such knowledge, in both a theoretical and structural sense, may contribute to a fuller understanding of visually impaired and reading impaired individuals, and in turn inform reading programmes in this area. Similarly, this knowledge may universally influence and inform the way in which reading is taught.

In conclusion, while some methodological concerns are evident in the experiment, there is some support for previous research and a dual-route model of word recognition (Coltheart et al., 1993). A structural explanation of this model is not supported, indeed, evidence suggests that a hemispheric interaction model may be more likely. The results also suggest that the association between the attentional resources and visual pathways involved in word recognition is more complex than is explained by a structural approach. Such outcomes clearly provide a foundation for future research that might contribute to a fuller understanding of the involvement of a RVF advantage and the role of spatial attention in word recognition processes.

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