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The effect of response mode on lateralized lexical decision performance

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Abstract

We examined the effect of manipulations of response programming, i.e. post-lexical decision making requirements, on lateralized lexical decision. Although response hand manipulations tend to elicit weaker laterality effects than those involving visual field of presentation, the implementation of different lateralized response strategies remains relatively unexplored. Four different response conditions were compared in a between-subjects design: (1) unimanual, (2) bimanual, (3) congruent visual field/response hand, and (4) confounded response hand/target lexicality response. It was observed that hemispheric specialization and interaction effects during the lexical decision task remained unchanged despite the very different response requirements. However, a priori examination of each condition revealed that some manipulations yielded a reduced power to detect laterality effects. The consistent observation of left hemisphere specialization, and both left and right hemisphere lexicality priming effects (interhemispheric transfer), indicate that these effects are relatively robust and unaffected by late occurring processes in the lexical decision task. It appears that the lateralized response mode neither determines nor reflects the laterality of decision processes. In contrast, the target visual half-field is critical for determining the deciding hemisphere and is a sensitive index of hemispheric specialization, as well as of directional interhemispheric transfer.

Keywords: Laterality; Hemispheric asymmetry; Hemispheric specialization; Word recognition

1. Introduction

For lateralized lexical decision, two effects are commonly observed. First, words are identified more quickly than non-words (Babkoff & Faust, 1988; Iacoboni & Zaidel, 1996; Mohr, Pulvermuller, & Zaidel, 1994; Zaidel & Rayman, 1994). Secondly, a right visual field advantage (RVFA) is often observed for word recognition, indicating specialization of the left hemisphere for performing the task. These factors commonly interact, as the RVF is observed for words, but less often for non-word stimuli (Babkoff & Ben-Uriah, 1983; Bradshaw & Gates, 1978; Iacoboni & Zaidel, 1996; Leiber, 1976). This has been taken as an indication that the left hemisphere possesses specialized word processing resources (Iacoboni & Zaidel, 1996; see Moscovitch (1986) for theoretical review of hemispheric lateralization).

In addition to exhibiting differences in visual field asymmetry, words and non-words also appear to elicit different patterns of interhemispheric interaction. Presentation of lexical stimuli in the unattended visual field, opposite to the target, allows for the measure of participation from the hemisphere contralateral to the one processing the target (Boles, 1990). Presenting duplicate copies of a target stimulus in both visual fields improves word identification performance (Mohr et al., 1994; Zaidel & Rayman, 1994), while presentation of different, distracter, letter strings, words or non-words, in the visual field opposite the target reduces word identification performance (Iacoboni & Zaidel, 1996). Conversely, non-word processing remains unaffected by stimuli in the opposite visual field (Iacoboni & Zaidel, 1996; Zaidel & Rayman, 1994). Thus, it appears that word targets benefit from inter-

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hemispheric exchange during successful processing whereas non-word targets are processed exclusively in the hemisphere initially receiving the stimulus.

Not only does the presence of distracter letter strings have a negative impact on word processing performance, the lexicality of the distracter may also have a significant impact. Iacoboni and Zaidel (1996) presented distracter words and non-words in the visual field opposite to the target in order to measure the influence of these stimuli on target lexical decision performance. Even though the presence of distracter letter strings led to an overall reduction in accuracy for target words, the loss was modulated by the lexical category of the distracter. When the distracter was a word, target word accuracy performance was less impacted than when the distracter letter string was a non-word. Termed lexicality priming, this effect was taken as further evidence of interhemispheric exchange during word processing due to the facilitative effect of congruent "word" presentation in the two hemispheres, compared to the incongruent non-word distracter/word target condition. Indeed, distracters within the same visual field as the target did not lead to significant lexicality priming (Zaidel & Rayman, 1994).

The target wordness by target visual field interaction commonly exhibited in this task is taken to reflect independent hemispheric processing strategies ("direct access" of Zaidel, Aboitiz, Clarke, Kaiser, & Matteson (1990)) and it is of interest to know whether this independence is affected by the laterality of the response arrangement. It is often assumed that hemispheric specialization and interaction occur during the early processing stages of lexical decision. Chiarello (1988) identified three stages involved in lexical decision: pre-lexical graphemic representation, lexical access, and post-lexical judgment or decision making. Pre-lexical processes involve visual-sensory analysis and translation of the stimulus (word or non-word) into some abstract but manipulatable encoded representation. The lexical stage mediates access to the mental lexicon, in the case of lexical decision matching the observed stimulus with some established lexical entry. Finally, post-lexical judgment involves making a word/non-word judgment for lexical decision tasks, pronunciation for naming tasks, or semantic integration for analogy tasks. It is unclear at which stage hemispheric differences are strongest, although there in some evidence that the two hemispheres do not differ in their pre-lexical processing abilities (Chiarello, 1988).

If hemispheric specialization and interaction effects are due to hemispheric differences in accessing the mental lexicon, these effects should be independent of the method by which subjects make response (i.e. the post-lexical phase). Measso and Zaidel (1990) examined the effect of variation in post-lexical decision making by comparing lexical decision performance for subjects using Yes/No versus Go/NoGo responses. For both response types subjects were instructed to either look for target words or non-words, with the difference between the two response types being that for the Yes/No condition subjects responded for each trial and for the Go/NoGo condition subjects only responded when the target matched a previously designated lexical category. The authors found that changes in response condition did not affect any aspect of hemispheric asymmetry observed for the task, suggesting that the manipulation affected later processing stages, after asymmetries had already been established.

Examining response bias is another way to explore post-lexical decision making processes. Since bias to identify a stimulus as a word or non-word occurs late in the lexical decision process, it represents one way the two hemispheres may differ in their post-lexical processing. Indeed, Chiarello, Nuding, and Pollock (1988) found a word bias for the left hemisphere and non-word bias for the right, accompanied by the standard RVF advantage in word recognition sensitivity. However, Measso and Zaidel (1990) observed a word bias for both hemispheres, and found that manipulating instructions given to subjects regarding response had no significant effect on the bias.

The current study systematically examined whether manipulation of response programming influences hemispheric asymmetry. One complication with behavioral laterality paradigms is that, as with visual field, response hand is also directly linked with the contralateral hemisphere. Because the right hand is controlled by the left hemisphere and the left hand by the right hemisphere, lateralization effects can, in principle, be predicted simply by the hand used to make manual response. However, response hand seldom exhibits the same right side advantage as seen with visual field, and a rarity of response hand by visual field interaction in previous research also suggests that choice of response hand often does not tax one hemisphere more than the other for lexical processing (Olk & Hartje, 2001; Zaidel, 1989; Zaidel et al., 1990). Some studies have avoided this potential confound by employing bimanual responses, while others used blocked unimanual response designs with alternate hands used in different blocks. Others ignore the issue altogether by instructing participants to make a manual response with one hand for words and with the other hand for non-words, although such an experimental design can introduce complex and problematic confounds when interpreting hemispheric asymmetries in lateralized paradigms.

It is plausible that different response arrangements engage different degrees of interhemispheric interaction. Although some research has observed differences in attention allocation between the visual fields based on response mode (Pollmann & Zaidel, 1999), very little is known about how they may influence hemispheric specialization or interaction during lexical decision. The purpose of the following study is to examine how manipulation of response mode affects hemispheric specialization and interaction. Four response modes are contrasted, based on their common presence in the literature and the different forms of hemispheric interaction involved for each. First, bimanual responses were included given the callosal interaction required for coordinated response. There is evidence that bimanual response involves cortical level coordination (Diedrichsen et al., 2003; Taniguchi et al., 2001;

Marion et al., 2003), and it is conceivable that such interaction in motor response may facilitate hemispheric interaction during the judgment itself (see Hazeltine et al. (2003) for related arguments). In contrast to bimanual responses, unimanual responses were also included because they, by definition, require only a single hemisphere's involvement for response. It is therefore reasonable to expect such a response arrangement may limit hemispheric interaction, or foster hemispheric independence, due to the asymmetric assigning of responsibility for response. This mode has been used extensively with split-brain patients, who naturally respond to lateralized stimuli with the ipsilateral hand.

Although they are used less often, two additional response modes are also included, although the hemispheric effects involved in their use is less clear. In the congruent response condition the hand of response depends on the visual field of presentation, with left hand response for LVF trials and right hand response for RVF trials. As such, this response strategy is a unimanual one with the choice of response hand depending on the nature of the trial itself (LVF or RVF trial). This requires the subject to observe the nature of the trial (word or non-word trial) before deciding which hand to use for response. Like the congruent mode, the confounded mode requires a decision about a feature of the target, in this case its lexical status rather than visual field. Although, to our knowledge, no studies have yet explored the consequences of such strategies upon hemispheric asymmetries, it is clear that such strategies require additional computations beyond that which is necessary for standard unimanual trials. Thus, it could be suspected that such response modes might disrupt standard hemispheric specialization and interaction effects. The purpose of this study is to compare hemispheric asymmetries for each of four response modes, and address potential similarities/differences in the context of the hemispheric interaction required for each.

2. Methods

2.1. Participants

Ninety-six right-handed UCLA undergraduate students and staff participated in the study (61 females, 35 males). Each subject had normal or corrected to normal vision and no history of neurological illness. Handedness was assessed using a modified version of the Edinburgh Handedness Inventory (Oldfield, 1971). This 17-item survey included questions regarding preferred handedness for simple daily tasks (e.g. drawing, writing, throwing), as well as questions regarding family sinistrality. All subjects reported possessing strong right-handed dominance. The majority of subjects were paid for their participation at a rate of $ 10 h. However, some subjects chose to participate for undergraduate course credit and were not financially compensated. A comparison of overall performance for paid and unpaid subjects revealed no differences.

2.2. Materials

Stimuli were 120 words and 120 non-words taken from the list used by Iacoboni and Zaidel (1996). All stimuli were between three and five letters in length. Words were divided into high- and low-frequency categories based on the frequency of written use norms developed by Francis and Kucera (1982). High-frequency words were defined as those occurring greater than 100 times per million and low-frequency words were defined as those occurring fewer than 20 times per million. Words were also divided into two categories based on their orthographic regularity (regular and irregular).

2.3. Procedure and design

Subjects were seated at a fixed distance of 57.3 cm from a 13 in Apple Color high-resolution RGB monitor, with their chins in a chin-rest and eyes aligned with a black fixation cross in the center of the screen. Subjects were instructed to maintain their gaze on the fixation point throughout the experiment. Each trial began with presentation of a lexical stimulus, followed by subject's response. The stimuli, which were black words or non-words on a white background, were displayed either to the left or right of the fixation point for 165 ms (11 refresh cycles of the monitor). This duration was chosen to minimize the possibility of scanning eye movements. The innermost edges of the stimuli were 1.0 degree of visual angle away from fixation, and stimuli subtended between one and three degrees in length.

Stimuli were underlined to discriminate the target from the distracter letter string, which was presented in the visual field opposite to the target. This distracter string was matched in length with the target but was not underlined. Subjects were instructed to ignore the distracter letter string and respond based solely on the lexical category of the target. On half the trials, the target and distracter were of the same lexical category (both words or non-words), and on the remaining trials they differed in lexical category. Response was made using response boxes placed directly in front each subject. Two response boxes were used, one for each hand, and each response box had two vertically aligned buttons. Subjects held the responses boxes with their index fingers on the top buttons and middle fingers on the bottom buttons. Subjects were divided into four equal groups based on the additional instructions given to them for how to respond.

2.4. Bimanual response

Subjects in the bimanual response condition responded simultaneously with both hands for each trial. Thus, they were told to press simultaneously the top button with the index fingers of both hands for all target words and the bottom button with the middle fingers of both hands for all target non-words.

2.5. *Blocked response*

Those subjects in the blocked response condition were instructed to respond unimanually in a blocked manner. Thus, in each block subjects used only their left or right hand to respond, and subjects switched response hand after each block. The index finger was used to press the top button in response to words and the middle finger was used to press the button in response to non-words.

2.6. *Congruent response*

For the congruent response condition, subjects were told to respond with the response hand located on the same side which the target stimulus was shown. Specifically, for LVF trials subjects were told to respond with their left hand and for RVF trials they responded with their right hands.

2.7. *Confounded response*

For those subjects in the confounded response condition, response hand was confounded with target wordness. For the first two blocks, subjects were told to press the top button with the index finger of one hand if they saw a word, and the top button with the index finger of the other hand if they saw a non-word. The hand assigned to words and non-words was switched after block two so that response measures for each hand and each target type was collected by the end of the fourth block.

Left visual field/left hand and RVF/right hand accuracy and latency measures were collected in each condition, providing measures of right and left hemisphere performance, respectively. The bimanual condition was the only exception, as only the first response was analyzed. Stimuli were presented in four 120 trial blocks, with each stimulus presented once as target and once as distracter in each visual field. Brief rest periods were provided between blocks to reduce subject fatigue, with breaks lasting between 2 and 5 min. The next trial began 3 s after the previous stimulus was shown. Subjects were also given a 24 trial practice to familiarize themselves with the response box mechanism. Computer testing lasted approximately 30 min.

3. Results

ANOVAs for accuracy and latency were performed with factors target wordness (word, non-word), distracter wordness (word, non-word), visual field (LVF, RVF), and response mode (bimanual, blocked, congruent, confounded). Accuracy results are represented in percent error. There was no main effect of response mode, but main effects of target wordness for both accuracy ($F_{1,92} = 21.04$, $P < .001$) and latency ($F_{1,92} = 72.40$, $P < .05$) showed that words were identified more quickly (678.2 and 723.9 ms) but with more errors (17.1 and 13.0%) than non-words. Main effects of visual field indicated that RVF trials were responded to both more quickly (687.6 and 714.5 ms; $F_{1,92} = 21.89$, $P < .001$) and with fewer errors (12.4 and 17.7%; $F_{1,92} = 63.08$, $P < 0.001$) than LVF trials. Target wordness and visual field interacted for accuracy ($F_{1,92} = 15.89$, $P < .001$, see Fig. 1) and latency ($F_{1,92} = 4.81$, $P < .05$). For accuracy, a strong RVF advantage was observed for target words ($F_{1,95} = 64.59$, $P < .001$), and a non-word advantage for LVF trials ($F_{1,95} = 26.31$, $P < .001$) but not for RVF trials. For latency, an RVF advantage was observed for target words (660.6 and 695.7 ms; $F_{1,95} = 29.02$, $P < .001$), and less strongly but still highly significantly for target non-words (714.5 and 733.3 ms; $F_{1,95} = 7.09$, $P < .01$). Response mode did not affect either of these factors, nor their interaction.

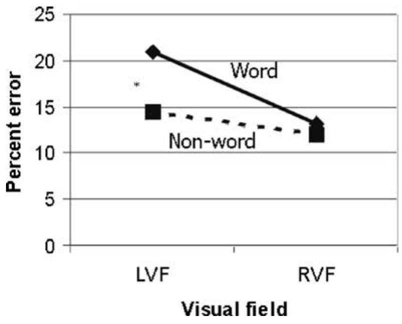

Fig. 1. The target wordness by visual field interaction for accuracy.

A target wordness by distracter wordness interaction (lexicality priming) occurred for response accuracy ($F_{1,92} = 4.32$, $P < .05$, see Fig. 2). For target words, subjects made fewer errors with distracter words compared to distracter non-words ($F_{1,95} = 6.93$, $P < .01$). However, distracter wordness had no effect on accuracy for target non-words. The target wordness by distracter wordness interaction was unaffected by visual field, i.e. there was no asymmetric lexicality priming. Response mode also did not interact with lexicality priming or its asymmetry. For response latency, distracter wordness interacted with visual field. Although an RVF advantage was observed for distracter word trials (687.0 and 707.5 ms; $F_{1,95} = 11.57$, $P < .001$) and distracter non-word trials (688.1 and

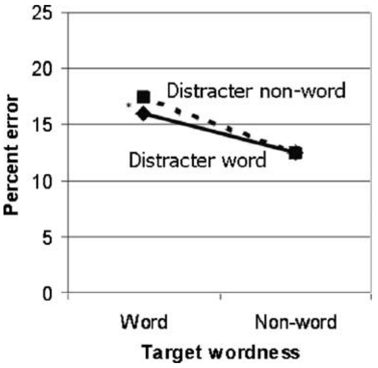

Fig. 2. The target wordness by distracter wordness interaction for accuracy.

721.5 ms; $F_{1,95} = 23.33$, $P < .001$), the effect was greater for distracter non-words, leading to a distracter word advantage for LVF targets ($F_{1,95} = 5.19$, $P < .05$). Again, response mode did not interact with any of these factors or their interactions.

3.1. Response groups

Because the primary interest of the current research study was the influence of response mode on hemispheric specialization and interaction, it was decided a priori that these factors were worthy of examination separately in each of the four response groups.

3.1.1. Bimanual response

Hemispheric specialization. A target wordness by visual field interaction occurred for both accuracy ($F_{1,23} = 12.47$, $P < .005$) and latency ($F_{1,23} = 6.50$, $P < .05$). For accuracy, RVF advantages were observed for both target words ($F_{1,23} = 35.94$, $P < .001$) and non-words ($F_{1,23} = 4.97$, $P < .05$), but was stronger for words, leading to a non-word advantage in the LVF ($F_{1,23} = 8.39$, $P < .01$) but not the RVF. For latency, the RVF advantage was significant only for target words ($F_{1,23} = 7.21$, $P < .05$), although a word advantage was observed for both the LVF ($F_{1,23} = 30.24$, $P < .001$) and RVF ($F_{1,23} = 40.41$, $P < .001$). Fig. 3 shows the target wordness by visual field interaction for each of the four response modes.

Hemispheric interaction. The target wordness by distracter wordness interaction was significant only for target latency ($F_{1,23} = 13.23$, $P < .005$). For target words, earlier responses were elicited with distracter words compared to distracter non-words ($F_{1,23} = 7.21$, $P < .05$), and a non-significant trend in the opposite direction was observed for

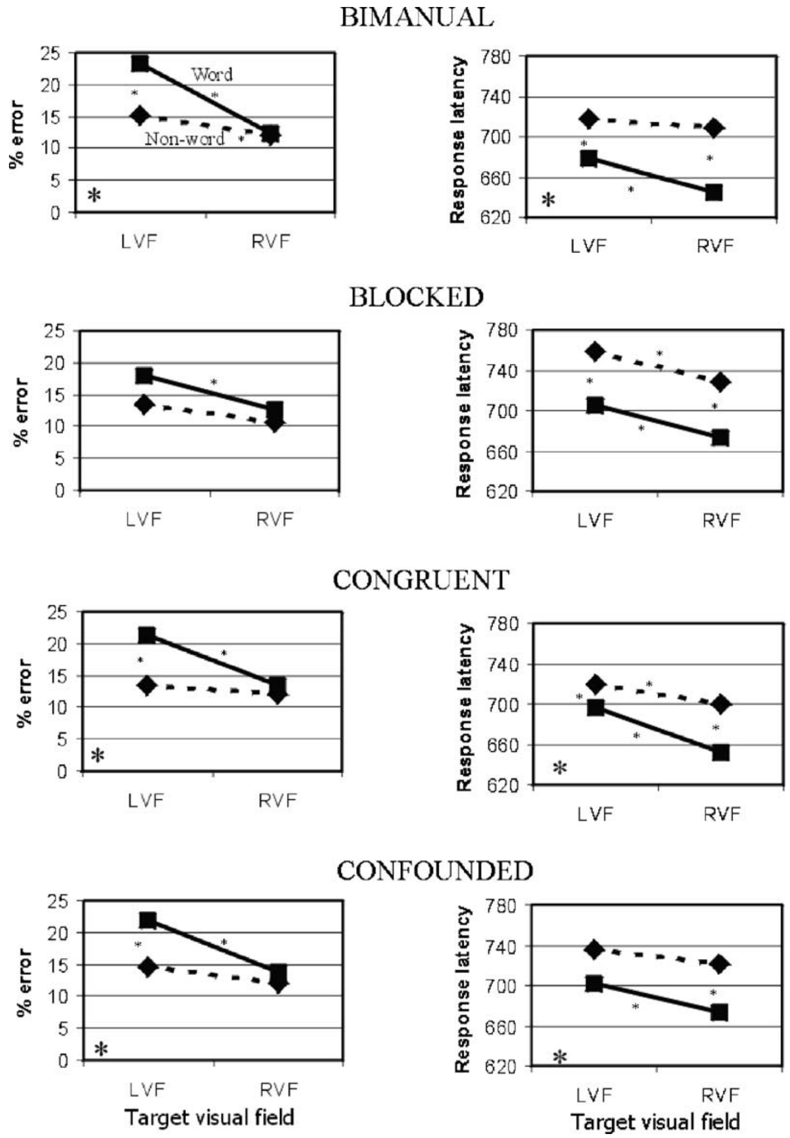

Fig. 3. Hemispheric specialization, as measured by the target wordness by visual field interaction, for each of the four response modes (significant interactions are indicated by asterisk).

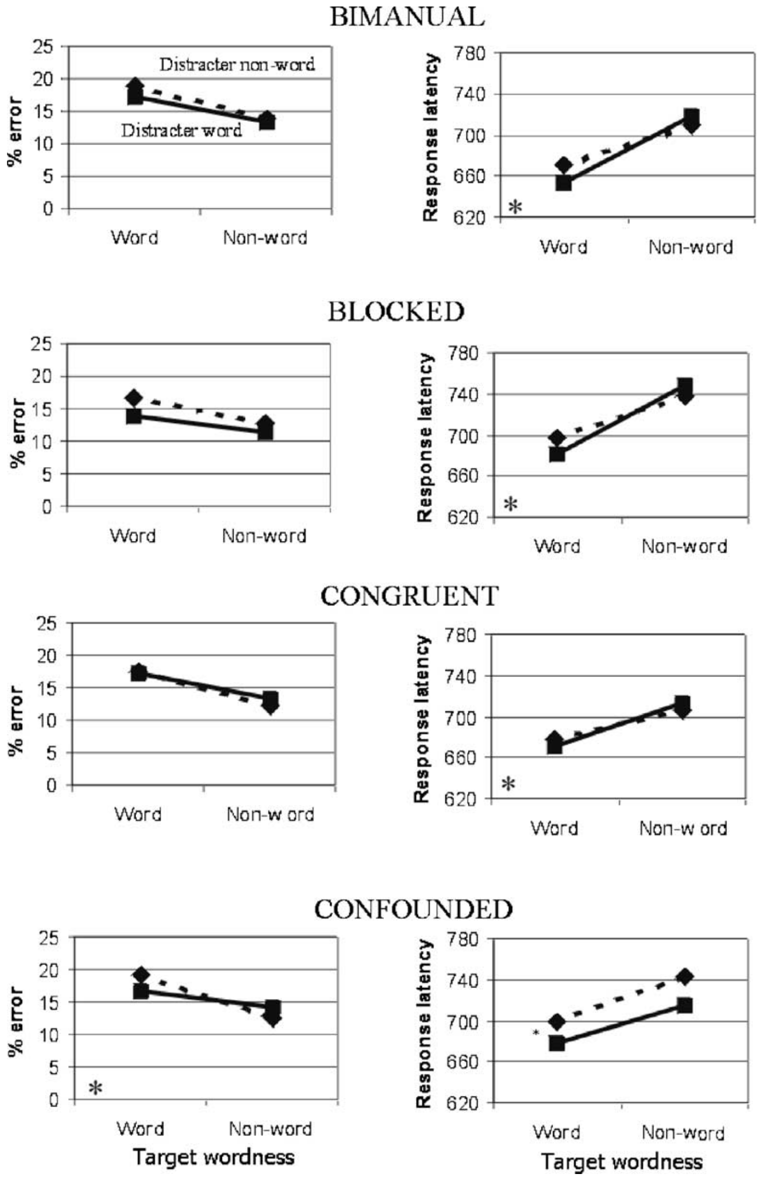

Fig. 4. Hemispheric interaction, as measured by the target wordness by distracter wordness interaction, for each of the four response modes (significant interactions indicated by asterisk).

target non-words. Fig. 4 shows the target wordness by distracter wordness interaction for each response mode.

3.1.2. Blocked response

Hemispheric specialization. The target wordness by visual field interaction did not approach significance for either response accuracy or latency.

Hemispheric interaction. A target wordness by distracter wordness interaction occurred only for response latency ($F_{1,23}$ = 13.00, $P < .005$). For target words, latency was reduced with distracter words compared to distracter non-words ($F_{1,23}$ = 7.09, $P < .05$), and a non-significant trend in the opposite direction was observed for target non-words.

Additional analyses. Because only half of the trials performed were included in the above analysis (those with congruent respond hand and visual field), results from all trials were examined as well. In effect, response hand was disregarded and all trials were included in the ANOVA (i.e. both left- and right-hand responses were examined for both LVF and RVF trials). Following this analysis, the target wordness by visual field interaction did reach significance for response accuracy ($F_{1,23}$ = 12.60, $P < .005$). A RVF advantage was observed for target word trials (87.0 and 85.4%; $F_{1,23}$ = 13.01, $P < .005$) but not target non-word trials (89.4 and 88.9%).

The target wordness by distracter wordness interaction failed to reach significance for either dependent measure.

3.1.3. Congruent response

Hemispheric specialization. A target wordness by visual field interaction occurred for both accuracy ($F_{1,23}$ = 6.83, $P <$

.05) and latency ($F_{1,23} = 6.33$, $P < .05$). For accuracy, an RVF advantage was observed only for target words ($F_{1,23} = 14.09$, $P < .001$), leading to a non-word advantage for LVF trials ($F_{1,23} = 12.14$, $P < .005$) but not for RVF trials. For response latency, a stronger RVF advantage occurred for target words ($F_{1,23} = 22.16$), than for target non-words ($F_{1,23} = 6.59$, $P < .05$). A stronger word advantage also occurred for RVF trials ($F_{1,23} = 26.40$, $P < .001$) than for LVF trials ($F_{1,23} = 4.41$, $P < .05$).

Hemispheric interaction. The target wordness by distracter wordness interaction was significant only for target latency ($F_{1,23} = 4.88$, $P < .05$). Although neither difference reached significance individually, target words were identified more quickly with distracter words and target non-words were identified more quickly with distracter non-words.

3.1.4. Confounded response

Hemispheric specialization. A target wordness by visual field interaction occurred only for accuracy ($F_{1,23} = 6.26$, $P < .05$). A significant RVF advantage was observed for target words ($F_{1,23} = 17.72$, $P < .001$), leading to a non-word advantage for LVF trials ($F_{1,23} = 11.39$, $P < .005$) but not for RVF trials.

Hemispheric interaction. Only response accuracy showed a target wordness by distracter wordness interaction ($F_{1,23} = 5.49$, $P < .05$). Although no difference reached significance individually, target words were identified more accurately with distracter words and target non-words were identified more accurately with distracter non-words.

Additional analyses. As with the blocked response condition, only half of the trials in the confounded group were included in the above analyses. To further examine all trials, an additional analysis was conducted disregarding response hand. As with blocked response, a significant target wordness by visual field interaction was observed for response accuracy ($F_{1,23} = 4.44$, $P < 0.05$). A RVF advantage was observed for word trials (85.9 and 83.1%; $F_{1,23} = 15.59$, $P < 0.005$) but not non-word trials (89.4 and 85.3%).

No target wordness by distracter wordness interaction occurred for either dependent measure.

3.2. Sensitivity and bias

In order to examine differences in response bias, as well as bias-free sensitivity for word recognition, the above analyses were also conducted with d' and $\ln \beta$ as dependent measures. However, because both word and non-word performance is simultaneously considered for the computation of both measures, ANOVAs included only factors visual field, distracter wordness, and response mode. For d', the only effect to reach significance was a main effect of visual field, with greater sensitivity for RVF trials compared to LVF trials (2.51 and 2.05; $F_{1,92} = 58.27$, $P < .001$). The same effect was significant for $\ln \beta$, with a stronger non-word bias for LVF trials compared to RVF trials (0.32 and 0.11; $F_{1,92} = 8.07$, $P < .01$). Response mode did not modify either of these effects.

3.3. Psycholinguistic effects

In order to examine psycholinguistic effects, ANOVAs for target word accuracy and latency were performed with the additional factors word frequency (high and low) and word orthography (regular and irregular). Main effects of word frequency were observed for both accuracy ($F_{1,93} = 3.84$, $P < .001$) and latency ($F_{1,93} = 151.823$, $P < .001$), with high-frequency words identified earlier (656.6 and 705.9 ms) and with fewer errors (9.7 and 24.5%) than low-frequency words. Word frequency interacted with visual field for both accuracy ($F_{1,93} = 7.47$, $P < .01$) and latency ($F_{1,93} = 6.88$, $P < .05$). For accuracy, an RVF advantage was observed for high-frequency words (6.7 and 12.9%; $F_{1,93} = 43.68$, $P < .001$) and to a stronger degree for low frequency words (19.8 and 29.5%; $F_{1,93} = 59.02$, $P < .001$). For latency, a strong RVF advantage was also observed for both low-frequency words (676.9 and 725.9 ms; $F_{1,93} = 33.28$, $P < .001$) and high-frequency words (633.4 and 668.0 ms; $F_{1,93} = 30.21$, $P < .001$). Word frequency and word regularity interacted for response latency ($F_{1,93} = 5.99$, $P < .05$). Although high-frequency words were identified earlier with both regular orthography (651.1 and 694.5 ms, $\mathrm{F}_{1,93} = 75.04$, $P < .001$) and irregular orthography (650.3 and 708.4 ms; $\mathrm{F}_{1,93} = 120.95$, $P < .001$), a regular orthography advantage was observed only for low frequency words ($F_{1,93} = 7.19$, $P < .01$). A three-way interaction between word frequency, regularity, and visual field occurred for both accuracy ($F_{1,93} = 7.23$, $P < .01$) and latency ($F_{1,93} = 3.87$, $P = .05$). For accuracy, the frequency by regularity interaction was significant only in the LVF ($F_{1,93} = 4.02$, $P < .05$), for which an irregular orthography advantage occurred for high frequency words (11.9 and 14.0%, $F_{1,93} = 4.01$, $P < .05$) but not for low frequency words (30.1 and 29.0%). For response latency, the frequency by regularity effect was also only significant in the LVF ($F_{1,93} = 7.37$, $P < .01$). However, a regular orthography advantage reached significance for low-frequency words (714.2 and 737.7 ms, $F_{1,93} = 8.30$, $P < .05$) but not for high-frequency words (668.2 and 667.9 ms).

Response mode was not found to interact with any psycholinguistic variable.

3.4. Sex effects

An analysis of sex effects was performed for all subjects by including sex as a between-subjects variable. Although no main effect of sex was observed, nor any lower level interactions, sex as found to interact with target wordness, distracter wordness, and visual field for response accuracy ($F_{1,94} = 6.86$, $P < .05$). Separate analyses of the three-way effect for males and females showed that it reached significance only for males ($F_{1,34} = 11.75$, $P < .005$). Examination of the target wordness by distracter wordness interaction showed lexicality priming in the LVF ($F_{1,34} = 22.02$, $P < .001$) but not the RVF. Specifically, for males LVF words were identified with fewer errors with distracter words (18.7 and 23.2%; $F_{1,34} = 15.48$, $P < .001$) and there was a non-significant trend for LVF non-words to be identified with fewer errors with distracter non-words (12.4 and 14.2%).

4. Discussion

Table 1 presents a summary of the findings, indicating positive and negative results for each response mode. Two results serve as the hallmark of lateralized lexical decision performance. First, a target wordness by visual field interaction signals hemispheric specialization and hemispheric independence for the task. Words typically show a strong RVF advantage, indicating left hemisphere specialization for the task. Although an RVF advantage is sometimes observed for non-word stimuli, it is almost never as strong as for words. These hemispheric differences usually lead to a word advantage in the RVF and sometimes lead to a non-word advantage in the LVF. These results were replicated in the current experiment, where an RVF advantage was observed for words in both accuracy and latency, and a weaker RVF advantage occurred for non-words only in response latency. This supports a direct access model of hemispheric specialization for the task and suggests that, overall, subjects performed normally on the task despite between-subject response mode manipulations. Greater word recognition sensitivity for the left hemisphere further supports a robust left hemisphere advantage for the task.

The second commonly observed result for lateralized lexical decision tasks is a lexicality priming effect. When distracter words or non-words are presented in the visual field contralateral to the target, accuracy and/or latency performance is highest when lexicality of the distracter matches that of the target (Iacoboni & Zaidel, 1996). Taken as a measure of interhemispheric communication during the task, this result was replicated in the current study for response accuracy. Distracter wordness affected target word identification performance in the expected direction, although it had no effect on target non-word performance. For response latency, the same result approached, but did not reach, significance. This result is in contrast to that of Iacoboni and Zaidel (1996), who observed lexicality priming for response latency but not accuracy. Although it is possible that response accuracy and latency tapped different cognitive resources in the two experiments, the nearly significant result in the current experiment suggests that with more experimental power the result might have been significant for both dependent measures.

An interesting difference between lexicality priming and hemispheric specialization effects is that the former displays a traditional speed-accuracy tradeoff whereas the latter does not, suggesting resource limited processing. For the above lexicality priming results, words are identified faster but less accurately than non-words, perhaps suggesting that the difference in performance between lexical types is due to strategic differences in how they are processed. Indeed, there is some initial indication that this is the case, and that non-words response latency is a particularly salient measure of the recognition strategy used by an subject (Weems & Zaidel, submitted for publication). The lack of a speed-accuracy tradeoff in hemispheric specialization, with RVF trials being both faster and more accurate, suggests that this difference is not due to strategic choice, but instead greater overall linguistic faculty of the left hemisphere compared to the right.

The most important result in the current experiment is that response mode did not interact with any of the experimental factors. This provides some indication that experimental manipulation of post-lexical processes has little effect on either hemispheric specialization or interaction. For each of the response modes used here, the analyzed data represented only congruent visual field/response hand performance. Therefore, differences between the groups, where observed, are likely due to different post-lexical strategies. There is conflicting prior evidence on whether changing response requirements should have influenced laterality effects for the task. Although Heister (1984) found that increased motor demands reduced laterality effects for some subjects, others (Measso & Zaidel, 1990) have observed minimal changes of laterality effects in lexical decision tasks following major changes in response requirements.

A priori analyses for each of the four response modes revealed that some response modes did show stronger and more consistent hemispheric specialization and interaction effects than others. For example, only bimanual and congruent response modes demonstrated hemispheric independence (a visual field by target wordness interaction) for both response accuracy and latency. These two conditions also represent the only ones in which for all trials no transfer between the hemispheres was absolutely necessary for response, thus enabling the hemisphere receiving the stimulus to be the same as the one making response. Specifically, for bimanual response, the hemisphere receiving the stimulus was capable of initiating the decision making without cortical interhemispheric transfer, although this is apparently not a common strategy.

Table 1
Summary of findings

	Bimanual		Blocked		Congruent		Confounded		All	
	Acc.	RT	Acc.	RT	Acc.	RT	Acc.	RT	Acc.	RT
Word main effect	+[a]	+	–	+	+[a]	+	+[a]	+	+[a]	+
Visual field main effect	+	+	+	+	+	+	+	–	+	
Target wordness by visual field	–	+	–	+	–	+	+	–	+	+
Target wordness by distracter wordness	–	+	–	+	–	+	+	–	+	–

[a] A non-word advantage was observed.

For congruent response the hemisphere receiving the stimulus makes the response. By contrast, only half of the trials for the other two response modes involved congruent visual field and response hand, and consequently the power to detect hemispheric asymmetries was reduced (i.e. the number of trials included in the final analysis was reduced by half). Additional analysis for the blocked and confounded response modes, disregarding response hand, showed hemispheric independence in one dependent measure: accuracy. Thus, it is possible that by having fewer trials in which visual field and response hand were congruent, power to detect hemispheric specialization effects was limited. However, it should be noted that since the interaction between target wordness, visual field, and response mode did not reach significance, these differences must be interpreted with caution.

Lexicality priming effects were observed for all response modes, although for each only in one dependent variable (accuracy or latency). This suggests that response mode did not significantly impact interhemispheric transfer for the task. The confounded response mode was unique, however, in that lexicality priming was observed in response accuracy, not in latency as with the other three response modes. The confounded condition was also the only one to show hemispheric specialization for only one dependent variable: again only for accuracy. Differences between how these dependent measures are influenced by response mode may be associated with the nature of the cognitive mechanisms involved in accuracy and latency performance. Other evidence has suggested that accuracy measures ease of lexical access whereas response latency taps strategy-related resources that affect efficiency of lexical access. It is possible that absence of latency effects in the confounded condition is related to the unique strategy demands placed on subjects in order to respond. Subjective reports from subjects after completing the experiment suggested that this was the most difficult condition to perform, and the greater demands placed on subjects may have reduced the ability to manipulate strategies and show effects in response latency.

Word frequency effects were observed in both hemispheres, with high frequency words identified both more quickly and accurately than low frequency words. There was some indication that left hemisphere specialization for the task may be greater for low frequency words, leading to a stronger RVF advantage and to a greater frequency effect in the right hemisphere. The interaction between word frequency and regularity in response latencies is a classic result of dual-route analyses (for review, see Hino & Lupker, 2000). The faster responses for regular words, compared to irregular words, only for low-frequency stimuli, indicates that the phonological processing mechanism plays a more important role for less familiar stimuli. However, in contrast to the standard hemispheric dual-route models, the frequency by regularity interaction was significant only in the LVF/right hemisphere. This is in direct contrast to most accounts which posit a phonological processing route only in the left hemisphere.

One possibility is that lateralized lexical decision may be more taxing for the right hemisphere, and therefore more likely to elicit phonological processing effects (Zaidel, 1998). Indeed, there is some indication that the right hemisphere participates in some aspects of phonological encoding when required by task demands (Coslett & Saffran, 1998). It is therefore possible that both hemispheres possess a phonological route for word recognition, but that the one in the left hemisphere is dominant whenever possible. Through tachistoscopic lateralization, the current design showed phonological processing abilities that otherwise might go undetected, or become overshadowed by phonological processing in the left hemisphere. Because performance is already high for the left hemisphere, it is further likely that phonological effects remain difficult to detect in the left hemisphere unless greater processing demands are associated with the task.

Sex effects revealed greater lexicality priming for males, isolated to the right hemisphere (LVF). Iacoboni and Zaidel (1996) also showed a trend for greater lexicality priming effects in the right hemisphere, presumably due to greater left-to-right hemisphere transfer compared to right-to-left transfer. However, this is the first time transfer asymmetry has varied as a function of sex. This result may be related to the greater overall laterality effects in males, with females possessing greater connectivity and therefore reduced need for asymmetric transfer (Zaidel, Aboitiz, Clarke, Kaiser, & Matteson, 1995). Weekes, Capetillo-Cunliffe, Rayman, Iacoboni, and Zaidel (1999) also observed complex sex effects during lexical decision, although these pertained to dual-route variables in lexical access. Clearly, further research concerning sex differences and lexical access in warranted.

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