Left- and Right-Handed Individuals Exhibit Opposite Response Times for Left and Right Visual Field Presentation of Stimuli

Abstract

It has been shown that left-handed individuals have a greater degree of neurological symmetry than do right-handed individuals (Eviator, Hellige, & Zaidel, 1997), and that there is evidence to support the idea of a specialised hemisphere being contralateral to the hand of preference (e.g. Hammond, 2002). We aimed to investigate the idea that attentional processing may be lateralised behaviourally and conducted an experiment to look at the differences in responses to a cued attentional paradigm, based on the work of Posner & Nissen (1978), showing that cue validity affects response time, and the work by Possamai (1991), showing that inhibition and hand of response are intrinsically linked. There was a difference in response observed between Left-Handed (LH) and Right-Handed (RH) participants; with the LH participants responding faster to stimuli in the RVF and vice versa for the RH participants. It is suggested that the lateralization of response in the non-specialised hemisphere for handedness, the hemisphere contralateral to hand of choice, has a processing advantage for covert attentional tasks. This study supports work done by Possamai (1991) and adds to the evidence supporting the higher levels of processing symmetry in LH relative to RH individuals.

Introduction

There have been both structural and functional asymmetries found in the human brain since Broca (1861) found that lesions producing language disorders were generally located in the left hemisphere. There is also evidence to suggest that the inherent laterality of brain organization is subject to variation with the hand preference of individuals. For example, Amunts et al (2000; 1996) found that in RH participants the left central sulcus was deeper than the right central sulcus and vice versa for the LH participants. This disparity in the relative depth of sulci between hemispheres was more pronounced in RH participants than LH participants indicating a greater asymmetry in RH individuals than in LH individuals. Amunts et al (2000) also found that hand preference was associated with increased connectivity in the specialised hemisphere, meaning the hemisphere contralateral to hand of preference. This finding was supported by Purves et al (1994) who found that RH individuals had larger right than left hands, indicating the relevant points of the sensorimotor systems are correspondingly asymmetrical; correspondingly the findings of Sörös et al (1999) showed, using magnetic source imaging (MSI), that there is strong cortical hand representation in RH but not LH participants, RH individuals exhibiting a larger representation of the specialised hand in contralateral cortex than the non-specialised hand, whereas LH individuals were more likely to exhibit symmetry in the relative cortical hand representations.

The use of spatial cues at stimulus locations enhances stimulus processing of a subsequently presented stimulus, reflecting the activation of mechanisms to shift attention to the cued stimulus location before its appearance (Corbetta & Shulman, 1998; Posner, 1980). The cue facilitates processing when in the attended location, a so-called valid cue, and impairs processing in the unattended location, a so-called invalid cue, eliciting faster and slower reaction times (RTs) respectively (Corbetta & Shulman, 1998; Danckert & Maruff, 1997; Griffin, Miniussi, & Nobre, 2002); where the cue is a false indicator of the position of the stimulus much longer reaction times (RTs) result (Posner et al., 1978).

Brain imaging studies have shown that activation for cued visual attention tasks is bilateral, but the stronger response is in the hemisphere contralateral to the attended field, showing that this contralateral hemisphere is more active during tasks involving shifting attention (e.g. Corbetta, Meizen, Shulman, & Peterson, 1993). These experiments have all been undertaken using RH participants, so any lateralization of function can only apply to RH individuals. The current study hopes to compare these responses with those of left-handed individuals in order to investigate the nature of the hemispheric specialisation on attention and whether it is in any way linked with handedness of an individual.

One study that did look at the cued-spatial location attentional phenomenon was that by Possamai (1991). She used left- and right-handed participants in her experiment, finding that there was a difference in the responses for each group. She found that the results for the left-handed individuals mirrored those of the right-handed individuals; the ispilateral hand to the target responded quicker than the hand contralateral to the hand of response. She also found that facilitation only occurred when participants responded with the hand ispilateral to stimulus presentation side. This suggests that there are motor and/or attentional processes that are reversed in left- as opposed to right-handed individuals. Bestelmeyer & Carey (2004) also looked at this aspect of attentional processing in the handedness of RH individuals, but they found that there was not an increased reaction time for invalidly cueing the right versus the left hand. They found that both hands were equally affected by the invalid cue.

The purpose of this study is to include left-handed individuals' responses in this debate and to investigate whether there are any differences for left-handed individuals relative to right-handed individuals. Therefore, the aim of this experiment, following on from Possamai (1991), was to investigate whether there is any psychophysical evidence for the increased levels of symmetry in LH participants and evidence for greater asymmetry in RH participants, using a cued reaction time task, which cues location but not hand of response. It was hypothesised were that there would be a difference in the lateralization of responses between LH and RH, involving faster reaction times for stimuli in the contralateral side of presentation to the 'specialised' hemisphere, as defined above, in each participant group (LH and RH); that cueing location would produce the expected pattern of results in line with previous research (Corbetta & Shulman, 1998; Posner, 1980), whereby valid cues, co-located with subsequent target, will elicit shorter reactions times than cues which are not co-located with the subsequent target.

Methods

Design

A 2x2x4 mixed design was employed. The between participants variable was handedness, left- (LH) or right handed (RH); the within participants variables were: side of presentation, left or right lower visual field, and cue validity, valid, partially-valid, partially-invalid and invalid.

Materials

Stimuli were produced using a visual stimulus generator and displayed on a colour monitor. Responses were made on a button box with contact switches. Lighting conditions were limited to one overhead spotlight located posterior to the participants and angled so there was no glare on the viewing monitor.

Stimulus Parameters

Stimuli were black and white sinusoidal luminance gratings 2.5cm square, angled ± 2 deg off vertical, and participants were asked to indicate the direction of tilt. Participants fixated a white square in the top right or left corner of the screen. Stimuli were preceded by a brief cue of 100ms duration, which was a white outline box matched in size to the stimulus. The cue and stimulus were presented at 5 locations and could be co-located, partially-overlapping, just touching, or separated, termed here valid, partially-valid, partially-invalid and invalid respectively. Stimuli were presented on a uniform grey background.

Timing Parameters

A cue appeared 500ms after the onset of the fixation point for 100ms, followed by a target 300ms later, which was onscreen for 100ms after which the screen was blank for 2 seconds or until the participant responded. There were 1300 trials per run, taking approximately 50 minutes, with breaks of 1-2 minutes every 15-20 minutes.

Participants

There were 19 right-handed participants (RH), 16 females and 3 males, mean age 23.1 years, range 18-44. There were 10 left-handed participants (LH), 9 females and 1 male, mean age 21.2 years, range 18-31. Handedness was assessed using the Edinburgh Handedness Inventory (EHI) (Oldfield, 1971). Mean score for the RH was +86.62 (range +62.5 to +100) and the mean score for the LH was -70.34 (range -23 to -100). The Participants were taken from an opportunity sample from the Psychology Department in a University in central UK. All participants had normal or corrected-to-normal vision.

Procedure

There were two versions of the experiment, presented either side of the lower visual field. One version was presented in the lower left visual quadrant, the LVF, and one was presented in the lower right visual quadrant, the RVF. All participants did both versions of the experiment.

Participants sat 2.1m away from the screen and looked at the fixation throughout the trials. The task, deemed necessary to maintain alertness in participants, was to judge the direction of tilt of the stimuli, signalling their choice with a button press. A right button press, performed with the right index finger, indicated a 'right-orientation' response, corresponding to a clockwise rotation from vertical, and a left button press, performed with the left index finger, indicated a 'left orientation' response, corresponding to an anticlockwise rotation from vertical. This was counterbalanced across participants, with the opposite response pattern being required of half the participants. There were 13 trial types in all: 3 valid, 4 partially-valid, 4 partially-invalid, and 2 invalid. Trials were randomly generated with equal probability giving an average of 100 trials for each of the 13 trial types. Participants were given practice at the task in pilot sessions to achieve at least 80% accuracy in the identification of target grating orientation before proceeding to the main data collections. Typically participants achieved this performance level after one 30-minute session. Participants were instructed to fixate on the fixation point in the top left or right-hand corner of the screen and to respond to the target only; they were instructed to not respond to the cue. Debriefing consisted of explaining to the participants what the significance of the cue was in relation to the target and what it was hoped it would do to the responses generated. All participants were told the results of their performance in terms of percentage accuracy and whether or not their responses conformed to the expected patterns.

Results

There was a general effect of type of cue, [$F(3,81)=50.874$, $p<0.001$] for both RH and LH participants with mean RTs in the valid condition being quicker than those in the invalid condition, and the RTs for the partial conditions falling in-between the two (see Figures 1a and 1b).

Figure 1a shows right-handed participants' reaction times to the individual stimuli: valid, partially-valid, partially-invalid and invalid, with no difference in reaction times between the right visual field (RVF) and left visual field (LVF) presentations of stimuli. Figure 1b shows left-handed participants' reaction times to the individual stimuli: valid, partially-valid, partially-invalid and invalid. For the LH participants, the stimuli on the RVF being responded to fastest, and the stimuli on the LVF being responded to slowest.

Figure 1a: Right-Handed Individuals Reaction Times across Conditions (in msec)

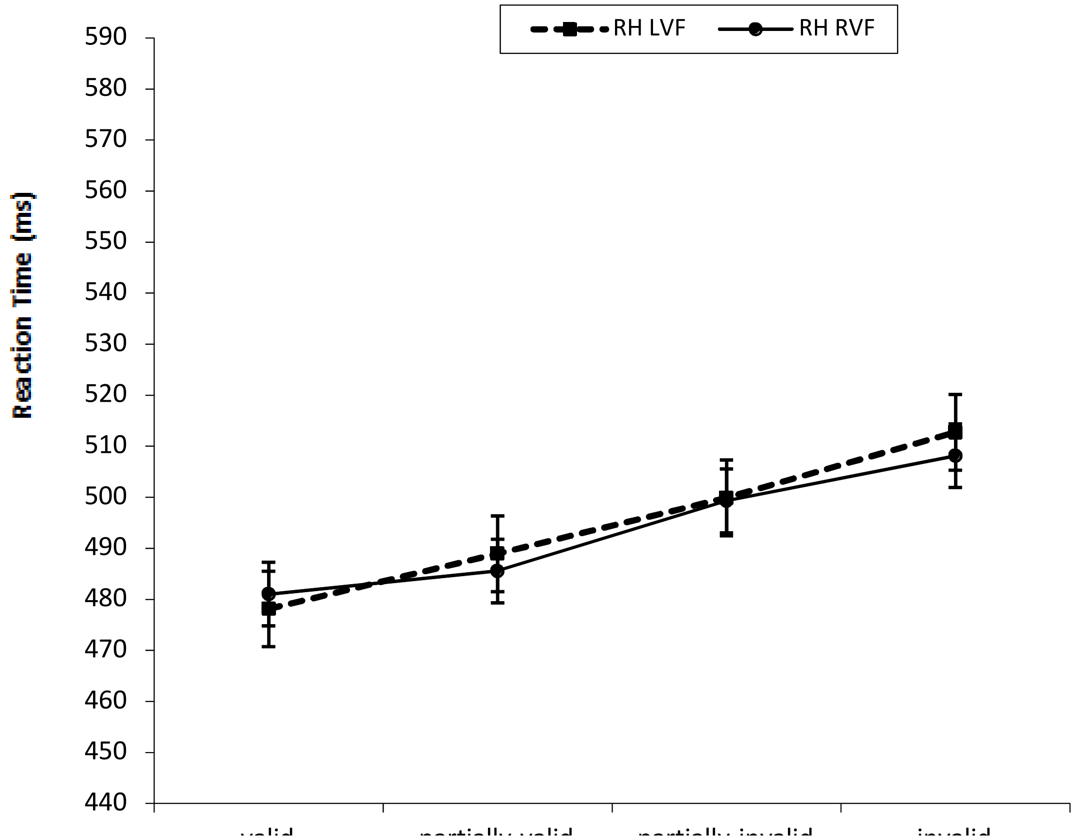
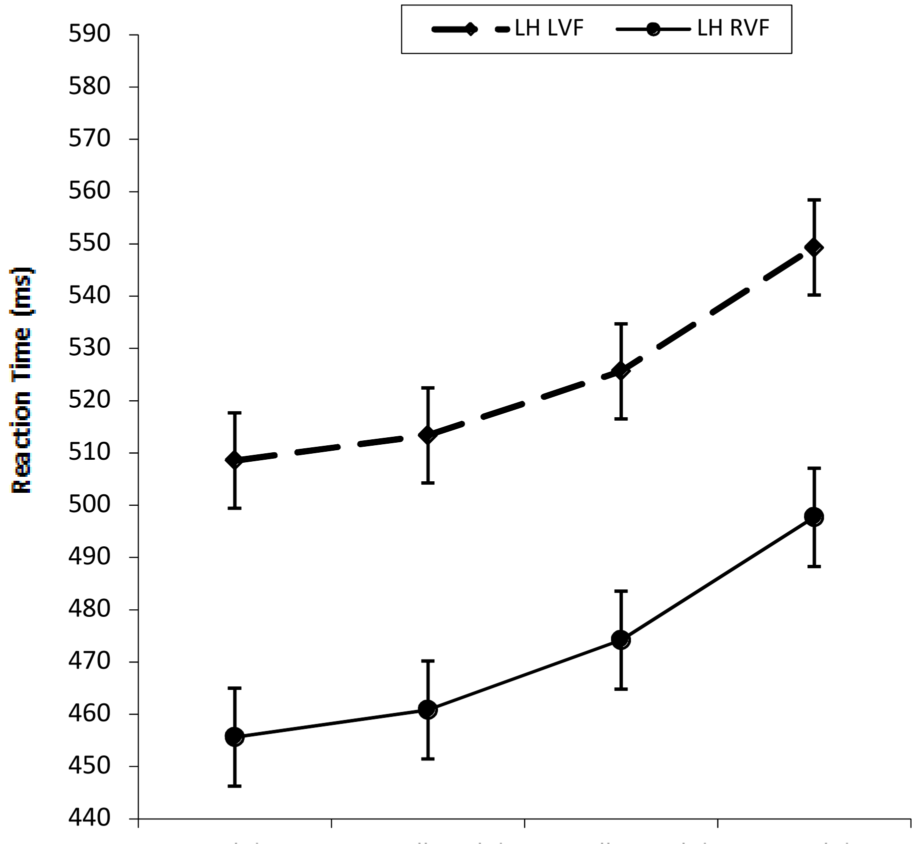
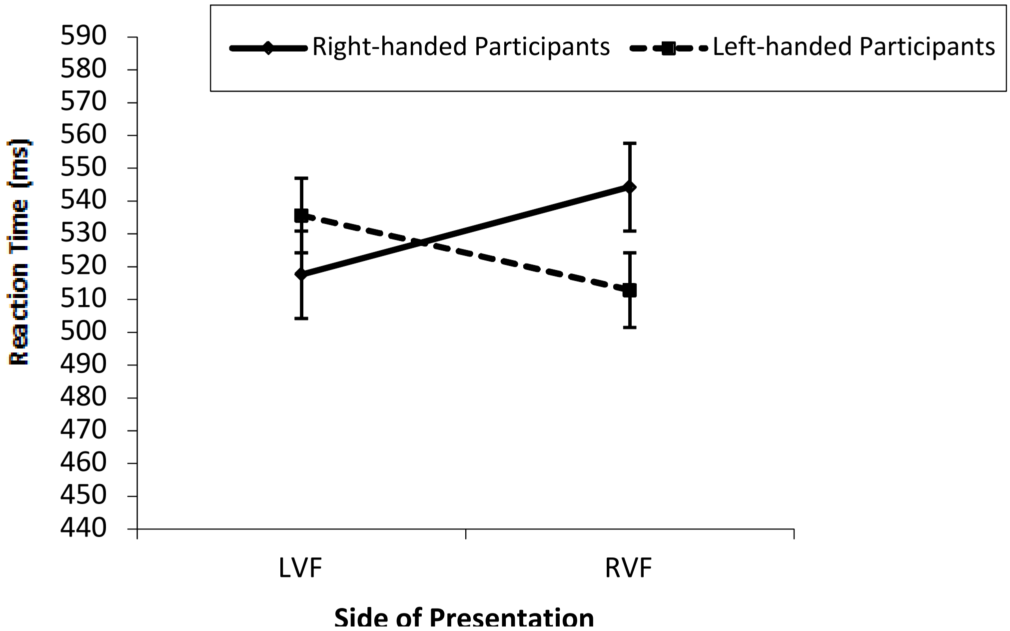

RH LVF
RH RVF
Reaction Time (ms)
590
580
570
560
550
540
530
520
510
500
490
480
470
460
450
440

Figure 1b: Left-Handed Individuals Reaction Times across Conditions (in msec)



When the effect of cue type was removed, the overall data showed that left-handed participants responded quicker to LVF (left visual field) stimulus presentation than RVF (right visual field) presentation, [t(79)=2.51,p<0.02] (see Figure 2); while the reverse was shown for the right-handed participants (see Figure 2), [t(79)=-3.811,p<0.001].

Figure 2: Participant's Combined Responses for all Conditions by Side of Presentation



Discussion

The results show that the responses are speeded for validly cued trials with respect to partially-valid, partially-invalid and invalid cues for both LH and RH, in line with Posner (1980). Responses are speeded for stimulus presentation contralateral to the hemisphere controlling hand of response, the specialised hemisphere, for both LH and RH individuals.

In line with many earlier reports (Corbetta, Kincade, Ollinger, McAvoy, & Shulman, 2000; Corbetta & Shulman, 1998; Posner, 1980; Rosen et al., 1999) using cued visual presentation we observed reaction time (RT) advantages for valid cues in both LH and RH participants (see Figures 1a and 1b). Similarly the results support the earlier findings of left and right hemispheric lateralization of responses between left-handed (LH) and right-handed (RH) participants (Eviator et al., 1997; Pierce et al., 1996; Possamai, 1991; Vallortigara et al., 1999). LH participants responded more rapidly to stimuli in the RVF while the RH responded more rapidly to stimuli in the LVF (see Figure 2).

In 1991, Possamai discussed the view that there was a priming effect of the cue on the motor response, stating that the cue primes the response, and at this point, inhibition from an invalid cue disrupts processing, not earlier in the attentional stream. She concludes by saying that the facilitation effect is attributable to the shortening of decision time, due to the priming nature of the cue; when the responding hand is ispilateral to the cue. She stops short, however, of linking handedness and the underlying nature of the attentional system. Instead she focuses on the inhibition part of the cued attentional response; concluding that the inhibition is where the locus of delay is in the contralateral hand of response, that the motor inhibition is slowed slightly for contralateral responses, in an additive effect for the expected delay from an invalid cue.

This study also lends itself to discussing the underlying attentional processing, due to the dramatic reversal of responses obtained from left- and right-handed individuals. Bestelmeyer & Carey (2004) found that hand of response had no effect on the pattern of response times to cued stimuli, with both hands producing faster RTs to valid than invalid conditions. The current experiment involved counterbalancing of the response hand across participant groups so the results do not represent hand of preference for LH and RH, which means the results here can be interpreted in terms of the underlying attentional processing and hemispheric differences.

It is possible to explain the visual field dichotomy shown in the results by suggesting that the non-specialised hemisphere may have a universal processing advantage in attentional processing, indicating some hemispheric reversal dominance in attentional processing in LH individuals relative to right-handed individuals. Dronkers & Knight (1988) observed right-sided spatial neglect in a left-handed individual, showing an example of reversed hemispheric specialisation for attentional processing. This is supported by the findings here and those of Possamai (1991).

All the results in the current experiment showed less extreme differences in cued attention responses for LH than RH participants. It can be proposed from these results that LH individuals show increased bilaterality of processing, and an increased incidence of reversed symmetry in comparison with RH individuals (Eviator et al., 1997). This research supports conclusions made by Possamai (1991) in that there is likely to be an increased facilitation during valid trials for the hand of response, which could be amplified in the preferred hand of response. Possamai (1991) argued for the inhibition in invalid trials (see Posner, 1980) being located in the motor part of the response, and this would appear to be supported by the data presented here.

This study adds to the evidence supporting this increased symmetry in LH individuals and suggests that the motor part of the response is the locus of the inhibition response, while facilitation is increased in the hand of preference.

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