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Research report

Upper visual field distractors preferentially bias attention to the left

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ABSTRACT

Pseudoneglect is influenced by vertical visual field stimulation, such that attentional biases are stronger for upper space distractors. Leftward biases result from right hemisphere visuospatial processing, and may be accentuated by additional right hemisphere activation during upper space distraction. Three experiments examined potential explanations for this finding. Experiment 1 controlled for perceptual grouping and leftward biases remained stronger in upper space. Experiment 2 used peripheral distractors to eliminate two further potential explanations: centre-of-mass and framing effects. Eye tracking was included to compare overt and covert attention. Findings supported the occurrence of a stronger leftward attentional bias during upper space distraction. Distractors were rarely fixated, suggesting covert attentional mechanisms are preferentially drawn toward upper space distractors. Experiment 3 employed a cueing paradigm that purposefully directed attention away from centre to determine whether pseudoneglect was influenced by overt attentional orienting. Results indicated that when attention was overtly directed away from centre, the strength of pseudoneglect did not differ based on visual field. It is concluded that covert attention toward upper space distractors recruits additional right hemisphere activation, leading existing leftward biases to be accentuated.

1. Introduction

Healthy individuals over-attend to information on the left side of space (Bowers & Heilman, 1980; Jewell & McCourt, 2000). This phenomenon is referred to as pseudoneglect due to similar underlying neural mechanisms with clinical hemispatial neglect (Bowers & Heilman, 1980; McCourt & Jewell, 1999). Neglect patients exhibit a strong attentional bias toward the right side, failing to perceive the left side of space, individual objects, or even their own body (Adair & Barrett, 2008; Heilman & Valenstein, 1979). Hemispatial neglect most often occurs following right hemisphere damage, particularly at the superior temporal gyrus and temporoparietal junction (Karnath & Rorden, 2012). This suggests that the right hemisphere plays a primary role in attending to the left side of

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space, such that patients with damage to the right hemisphere are unable to attend toward the left. Although smaller than the bias observed amongst neglect patients, pseudoneglect is reliably observed in healthy populations (Jewell & McCourt, 2000).

As a result of contralateral innervation, it has long been suggested that attentional biases toward the left side of space occur because the right hemisphere preferentially controls visuospatial attention (Kinsbourne, 1970). Neuroimaging data have indicated that the intraparietal sulcus, temporoparietal junction and lateral peristriate cortex in the right hemisphere are preferentially activated during visuospatial tasks (Bjoertomt, Cowey, & Walsh, 2002; Çiçek, Deouell, & Knight, 2009; Fink et al., 2000; Fink, Marshall, Weiss, & Zilles, 2001; Foxe, McCourt, & Javitt, 2003). Further, left visual field stimuli activate right hemisphere visuospatial attention networks (Siman-Tov et al., 2007), supporting the suggestion that pseudoneglect occurs as a result of greater right hemisphere activation, which leads attention to be more strongly directed to the left side.

Pseudoneglect occurs across a variety of tasks, including line bisection (Luh, 1995; McCourt & Jewell, 1999) and landmark (Dufour, Touzalin, & Candas, 2007; Thomas, Loetscher, & Nicholls, 2012) tasks. On line bisection tasks, participants either manually bisect lines to the left of centre (Luh, 1995), or indicate that pre-bisected lines are transected to the left of centre (McCourt & Jewell, 1999). On the landmark task, the left side of the line is chosen as being longer than the right, because more attention is directed toward the left side (Dufour et al., 2007; Thomas, Loetscher, et al., 2012).

Interestingly, attentional asymmetries exist, not only in the horizontal dimension, but also in the vertical dimension. For vertical stimuli, more attention is directed toward the upper portion of the stimulus (Drain & Reuter-Lorenz, 1996; Jeerakathil & Kirk, 1994; Nicholls, Mattingley, Berberovic, Smith, & Bradshaw, 2004). When horizontal stimuli are presented exclusively within one visual field, findings have been mixed as pseudoneglect has been observed to be stronger in both the upper and lower visual fields (Barrett, Crosson, Crucian, & Heilman, 2000; Loughnane, Shanley, Lalor, & O'Connell, 2014; McCourt & Jewell, 1999 Thomas & Elias, 2010, 2011, 2012).

Previc (1990, 1998) suggested that vertical processing differences result from differential involvement of the two visual streams. The lower visual field is processed as a part of peripersonal space, whereas the upper visual field is associated with extrapersonal space. This mapping is consistent with lower space stimuli being in a manipulable location and upper space stimuli being located at a distance (Previc, 1990). Furthermore, Previc (1990, 1998) postulated that the dorsal stream preferentially processes the lower visual field, whereas the ventral stream processes the upper visual field. Visuospatial processing differences on line bisection tasks consistent with these processing differences have been reported where activation is greater in the dorsal stream when performed in peripersonal space and within the ventral stream when acting in extrapersonal space (Bjoertomt et al., 2002; Weiss et al., 2000).

The dorsal visual stream is implicated in processing motion and determining location (i.e., where pathway). In contrast, the ventral stream is involved in processing colour and object recognition (i.e., what pathway). It has been suggested that visuospatial tasks might primarily engage the dorsal visual stream (Thomas, Schneider, Gutwin, & Elias, 2012); however, the task employed in this study involved detecting differences in brightness, which relies more heavily on the dorsal stream. Tasks that require participants to determine the size/form of an object might engage the ventral stream and lead to upper visual field processing advantages. Indeed, Thomas and Elias (2011) observed stronger leftward biases in the upper visual field when viewing times were limited to 150 msec, whereas leftward biases were stronger in the lower visual field during free-viewing.

Interestingly, Mao, Zhou, Zhou, and Han (2007) employed functional magnetic resonance imaging (fMRI) during a target detection task to examine which areas were differentially activated by attentional shifts along the vertical and horizontal axes. Of particular importance, additional activation within the right hemisphere occurred for upper targets, but not for lower ones. Mao et al. (2007) concluded that visuospatial attention toward the upper visual field leads to additional activation within the right hemisphere.

The ventral attention network, which biases the dorsal network toward unexpected or unpredictable stimuli, is lateralised to the right hemisphere (Corbetta & Shulman, 2011; Vossel, Geng, & Fink, 2014). It has been shown the depleting the ventral network shifts attention rightward (Benwell, Thut, Learmonth, & Harvey, 2013; Newman, O'Connell, & Bellgrove 2013; O'Connell, Schneider, Hester, Mattingley, & Bellgrove, 2011). In contrast to this, unpredictable distractor stimuli could increase activation of the ventral attention network and bias attention more strongly toward the left and subsequently increase pseudoneglect.

Although the vertical elevation of a stimulus influences the strength of pseudoneglect, what occurs when the visuospatial task is located in the centre of the visual field and distractor stimuli are positioned in upper or lower space? While much research has been devoted to examining hemispheric asymmetries in relation to horizontal space (Jewell & McCourt, 2000; Kinsbourne, 1970; Nicholls et al., 2012), the interaction of horizontal and vertical space in visuospatial attention remains understudied. As left visual field and upper visual field stimuli both activate the right hemisphere, it is possible that stimuli within the upper visual field preferentially attract attention and influence attentional biases.

To test the interaction between attention in the vertical and horizontal planes, Nicholls et al. (2012) presented a landmark task in the centre of the visual field, with distractor stimuli located in either the upper or the lower visual field. Distractors, despite being entirely task irrelevant, have the ability to draw attentional resources away from the primary task in an automatic manner, which occurs outside of conscious control (Lavie, 2005). Nicholls et al. (2012) observed stronger leftward biases when irrelevant distractors were in the upper visual field, suggesting an intrinsic link between horizontal and vertical space in visuospatial attention. They conclude that additional activation within the right hemisphere, elicited by upper visual field stimulation, in combination with the right hemisphere activation that occurs during visuospatial tasks, leads pre-existing leftward attentional biases to be accentuated.