RESEARCH REPORT

THE EFFECT OF BODY AND ENVIRONMENT-CENTRED COORDINATES ON FREE-VIEWING PERCEPTUAL ASYMMETRIES FOR VERTICAL AND HORIZONTAL STIMULI

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Abstract

Leftward and upward perceptual biases are commonly reported for horizontal and vertical stimuli, respectively. It is unclear, however, whether these biases are based upon body or environment-centred coordinates. Two experiments examined the contribution of these coordinate systems to free-viewing vertical and horizontal perceptual biases. In Experiment 1, normal participants (n = 35) made forced-choice luminance judgments on two mirror-reversed luminance gradients (the 'greyscales' task) presented in vertical and horizontal orientations. Body and environment-based coordinates were dissociated by tilting participants' heads to the left or right. A leftward and upward bias, which was observed in the horizontal and vertical conditions (respectively) when the head was upright, was extinguished when the head was tilted. Results indicated a dual reliance on body and environmental coordinates with some suggestion that the upward bias was more dependent on environmental coordinates. In Experiment 2 the same stimuli were presented as participants (n = 24) adopted an upright or supine pose. Once again, leftward and upward biases were observed in the upright condition. The leftward bias persisted in the supine condition whereas the upward bias was eliminated. Results demonstrate that the leftward bias is based predominantly on body coordinates whereas the upward bias is reliant on environmental/gravitational coordinates. The possibility that the neural basis for the biases lies in the inter-modal centres of the intraparietal region of the right hemisphere is discussed.

Key words: neglect, left, right, pseudoneglect, attention, gravity

Introduction

By moving our eyes across a centrally presented stimulus under free-viewing conditions, we have the potential to assimilate information equally from all parts of the stimulus. Despite this potential, it appears that there are systematic biases in perceived salience along the vertical and horizontal axes of a stimulus. For horizontally aligned stimuli, the left end is typically judged to be more salient than is the right. Thus, for a task such as line bisection, normal participants transect the line slightly to the left of its true centre (e.g., Post et al., 2001; Rueckert et al., 2002), presumably because the left side of the line is 'weighted' more heavily than is the right (for a review of this phenomenon, see Jewell and McCourt, 2000). Because this leftward bias mirrors the strong rightward bias for line bisection observed in spatial neglect patients (Mattingley et al., 1994), the bias is often referred to as 'pseudoneglect' (Bowers and Heilman, 1980). For vertically aligned stimuli, the upper features are overestimated relative to the lower features. Thus, for a line bisection task, the stimulus is typically transected slightly above its true centre (Drain and Reuter-Lorenz, 1996; Bradshaw et al., 1985; McCourt and Olafson, 1997; Van Vugt et al., 2000). Leftward and upward biases have been reported for judgements other than length, such as numerosity (Luh et al., 1991; Nicholls et al., 1999), luminance (Nicholls et al., 1999, 2004) and size (Nicholls et al., 1999). These tasks appear to engage a similar, but not identical, set of cognitive and neural mechanisms to those engaged by the line bisection task (Luh et al., 1991; Nicholls et al., 1999).

A variety of explanations have been put forward to account for the leftward and upward biases. While these theories often share a number of features, they also have a number of unique characteristics. For example, asymmetries in activation have been proposed to account for both the leftward (Kinsbourne, 1970; Vingiano, 1991) and upward (Drain and Reuter-Lorenz, 1996) biases. However, asymmetries in activation between the *cerebral hemispheres* are thought to underlie the leftward bias (Schiff and Truchon, 1993; but c.f., Nicholls et al., 2001) whereas activation asymmetries between the *ventral and dorsal visual streams* are believed to cause the upward bias (Drain and Reuter-Lorenz, 1996). Leftward and upward biases have also both been explained with reference to object-centred biases. That is, we attend more to the leftward or upper features of an object because they have a special significance within the object. Leftward features of an object may have a special significance for readers of Western text because this is the side on which reading is initiated. In support of this proposition, Chokron et al. (1997) found that readers of Hebrew (right-to-left) showed no significant bias for a line extension task, whereas readers of French (left-to-right) significantly underconstructed the left side of the line (also see, Chokron and Imbert, 1993; Chokron and De Agostini, 1995; but c.f., Nicholls and Roberts, 2002). The upper features of a stimulus may be more important than the lower features because the upper features of an object (for example, the face in relation to the body) generally contain more information than the lower features (Jeerakathil and Kirk, 1994). Jeerakathil and Kirk (1994) demonstrated the importance of the concept of 'upper' by placing labels on either end of a line (i.e., 'top' and 'bottom') and then turning the lines with respect to the viewer. By opposing or combining retinotopic and labelled coordinates, they observed a reduction or accentuation of the upward bias for vertical lines when the labels and gravitational coordinates were discordant or concordant (respectively). A bias towards the end that was labelled 'top' was also found for horizontal and radial line orientations.

In order for leftward and upward biases to manifest, spatial maps, which code the orientation, location and size of objects, need to be constructed. These maps are multimodal and include input from the visual, tactual, proprioceptive and vestibular senses. Mennemeier et al. (1994) suggested that spatial maps could be constructed from at least three frames of reference. The first, centred on the body, appears to rely on multiple frames of reference aligned with the position of the trunk, head and eyes (Bradshaw et al., 1983). The second, aligned with environmental coordinates, appears to be particularly reliant upon gravitational forces (Shephard and Hurwitz, 1984). Finally, object-centred coordinates are known to play a role in perceptual asymmetries (Jeerakathil and Kirk, 1994).

Ladavas (1987) investigated the effect of body- and environment-centred coordinates on spatial neglect by measuring simple RTs to targets presented above and to the left or right of a central fixation point. Previous research with stimuli of this type demonstrates that a right visual field advantage will be observed when the head is upright (Ladavas, 1987). Environment and body-centred coordinates were dissociated by tilting patients' heads to the left or right. Ladavas found an advantage for targets presented in the right hemispace (gravitationally defined) and in the right visual field (head defined) and thus concluded that both gravitational and retinal coordinates play a role in left neglect. Mennemeier et al. (1994) examined the influence of environment and body-centred reference frames in two patients who neglected opposite dimensions of space. The patients were asked to bisect lines that were presented vertically, horizontally or radially[1]. Environmental and body-centred coordinates were manipulated by asking participants to lie on their left or right sides or to lie in a prone or supine position. Mennemeier et al. (1994) found that when body and gravity-centred coordinates were opposed, gravity-centred coordinates were a better predictor of performance and therefore concluded that gravitational coordinates dominated the distribution of spatial attention in neglect.

While testing the effect of the different coordinate systems on neglect, Mennemeier et al. (1994) also tested a group of normal participants. They bisected vertical, horizontal and radial lines in the same body orientations used for the clinical patients. Significant upward and distal biases were observed for vertical and radial lines, respectively. However, a leftward bias for horizontal lines failed to reach significance. For the prone and supine positions, Mennemeier et al. (1994) found that the vertical and radial biases followed body reference frames. They thus concluded that perceptual biases in normal participants "appear to be more influenced by body- than environment-centred reference frames" (p. 1019). However, this conclusion appears to be limited to the prone and supine conditions. When participants lay on their left or right sides, there were no significant horizontal or vertical biases. Thus, when vertical and horizontal coordinate systems are opposed, free-viewing perceptual asymmetries in the horizontal and vertical dimensions are eliminated.

Bradshaw et al. (1985) also examined the effect of body and environmental coordinates on line bisection in a normal population. Participants adjusted a rod so that its two extremities were equidistant from a central point. The rod could be aligned vertically or horizontally and participants performed the task sitting upright or lying on their left or right sides. In the upright condition, a significant leftward and non-significant upward bias was observed for the horizontal and vertical stimulus orientations (respectively). When gravitational and body coordinates were dissociated, the biases tended to be attenuated. However, for vertical stimuli (as defined by the observer) a non-significant upward bias in the upright condition was transformed into a significant upward bias in the 'lie on left' condition. The increased bias observed in this condition presumably reflects the summation of an upward bias (from the viewpoint of the observer) and a leftward bias (as defined by gravity). The evidence in favour of an additive effect between the two coordinate systems is not strong, however, as an additive pattern was not observed for any other condition.

It can be seen that the effect of body and environment-based coordinates on free-viewing

[1]The orientation of stimuli was defined with reference to the participant's trunk in the Mennemeier et al. (1994) study and this convention will be used throughout the present paper.