Neuroscience and Biobehavioral Reviews 55 (2015) 223–233

Contents lists available at ScienceDirect

Neuroscience and Biobehavioral Reviews

journal homepage: www.elsevier.com/locate/neubiorev

Review

Altered visual perception near the hands: A critical review of attentional and neurophysiological models

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ARTICLE INFO

Article history:
Received 17 July 2014
Received in revised form 16 March 2015
Accepted 5 May 2015
Available online 12 May 2015

Keywords:
Near-hand space
Peripersonal space
Attention
Attentional spotlight
Magnocellular
Parvocellular
Spatial acuity
Temporal acuity
Bimodal neurons
Bimodal cells

ABSTRACT

Visual perception changes as a function of hand proximity. While various theoretical accounts have been offered for this alteration (attentional prioritisation, bimodal cell involvement, detailed evaluation, and magnocellular neuron input enhancement), the current literature lacks consensus on these mechanisms. The purpose of this review, therefore, is to critically review the existing body of literature in light of these distinct theoretical accounts. We find that a growing number of results support the magnocellular (M-cell) enhancement account, and are difficult to reconcile with general attention-based explanations. Despite this key theoretical development in the field, there has been some ambiguity with interpretations offered in recent papers, for example, equating the existing attentional and M-cell based explanations, when in fact they make contrasting predictions. We therefore highlight the differential predictions arising from the distinct theoretical accounts. Importantly, however, we also offer novel perspectives that synthesises the role of attention and neurophysiological mechanisms in understanding altered visual perception near the hands. We envisage that this theoretical development will ensure that the field can progress from documenting behavioural differences, to a consensus on the underlying visual and neurophysiological mechanisms.

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1. Near-hand space

A body of literature indicates that visual perception and performance is altered when visual stimuli occur in the space near the hands (see Brockmole et al., 2013; for a review). That is, identical visual information is processed differently dependent on the relationship between the visual information and the observer's hands. The typical laboratory set-up in which near versus far-hand space is manipulated is to have observers place their hands on response-equipment attached to either side of the screen, rendering the visual stimuli displayed on the computer screen in "near-hand space", versus having the observer place their hands on response-equipment in their lap, or on the desk in front of them, rendering

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http://dx.doi.org/10.1016/j.neubiorev.2015.05.006
0149-7634/

the visual stimuli on the screen in "far-hand space". A plethora of evidence suggests that such near versus far-hand set-up produces differences in performance on a variety of visual tasks (Abrams et al., 2008; Adam et al., 2012; Chan et al., 2013; Cosman and Vecera, 2010; Davoli et al., 2010; Garza et al., 2013; Goodhew et al., 2013a, 2014a,b,c; Gozli et al., 2014, 2012; Tseng and Bridgeman, 2011). Importantly, this altered perception is attributable to the hand proximity, rather than hand visibility or response mode, as similar effects occur even when the observer's hands are concealed from their view, and when they use their feet rather than their hands to respond (Abrams et al., 2008; Reed et al., 2006). Furthermore, it is hand proximity, rather than posture, that creates these effects (Weidler and Abrams, 2013). Thus, altered visual perception reflects the effect of hand proximity, rather than some other variable, most likely due to a mechanism that registers combined proprioceptive and visual input.

Given the body of evidence for altered visual perception in near-hand space, a key question pertains to the nature and therefore mechanism underlying this difference. A number of different theoretical accounts have been put forward. Initial accounts drew on visual attention as an explanation. However, as this review will discuss, there is some ambiguity and a lack of precision about the use of 'visual attention' to explain quite a diverse and at times even apparently contradictory pattern of findings. A more recent account draws on more precise physiological underpinnings, specifically, the interplay of the two major classes of visual cells, magnocellular neurons (M-cells) and parvocellular neurons (P-cells). This account has the advantage of making clearer, more precise predictions, and evidence is accumulating that this account can explain elegantly what the general attentional accounts struggle to account for. The purpose of this review is to highlight this crucial theoretical development, because there remains a tendency to rely on the earlier, less-developed theoretical accounts to explain findings, with either no reference to the more recent theories or the erroneous assumption that they are different ways of describing the same theory (e.g., Park et al., 2013; Reed et al., 2013). Following this, however, we also offer some new insights into how a more nuanced understanding of visual attention, in particular how different mechanisms of attention relate to underlying neurophysiology, may ultimately unite accounts based on attention versus input biases from magnocellular versus parvocellular neurons.

2. Visual attention

Visual attention is a process in which particular stimuli are selected for privileged processing at the expense of others. This process of selection is thought to be necessary, so as not to overwhelm the brain's limited perceptual and cognitive processing resources (Broadbent, 1958; Desimone and Duncan, 1995; Kastner and Pinsk, 2004). This process can operate in a bottom-up or reflexive manner, in which brute stimulus energy or salience determines the stimuli that are selected (Jonides and Yantis, 1988; Yantis and Jonides, 1984), or it can operate in a top-down or more strategic way, in which an observer's goals guide selection (e.g., Becker et al., 2010; Folk et al., 1992; Goodhew et al., 2014a,b,c; Most et al., 2001; Wyble et al., 2013).

2.1. Attentional prioritisation theory and bimodal cells

Reed et al. (2006) offered the first theoretical account for altered visual perception near the hands, proposing that near-hand space enjoys *attentional prioritisation*. This explanation was motivated by their results from a covert attentional orienting paradigm (Posner et al., 1987). In their paradigm, participants' task was to detect the onset of a target – a filled-in square (i.e., a rapid change in luminance at the target location) that could appear at one of two possible locations, which were demarcated with outline squares. A cue, which consisted of the border of one of the two squares darkening, preceded the target. The cue was 70% valid, which means that the cue correctly signalled the location of the target on 70% of trials (valid trials) and the target appeared in the uncued location on the other 30% of trials (invalid trials), and response times (RTs) to detect the target were measured as a function of cue validity. These authors manipulated near versus far hand space in a slightly different manner from most subsequent studies: participants placed a single outstretched hand, with their palm facing towards the centre of the screen and the tips of their fingers touching the screen. This rendered the stimuli on the same side of the screen as their hand in "near-hand space", whereas stimuli appearing on the opposite side of the screen were deemed "far-hand space". Reed et al. found that participants were faster to respond to targets when they appeared in near-hand space compared with when they appeared in far-hand space. Importantly, however, there was no change in cueing (the difference in RT between valid and invalid trials) between near and far-hand space. Since cueing is the hallmark of a shift of spatial attention (Posner, 1980), this indicates that participants' efficiency in shifting their attention from an invalidly cued location to the location of the target was unaffected by hand proximity. Subsequent control experiments eliminated explanations for this difference between general accelerated processing without specific attentional effects based on visual anchoring (a board aligned to the screen in place of the hand had no such effect), or hand visibility (the same effects were observed when the hands were concealed from the observer as when they were visible). This led Reed and colleagues to suggest that there is a baseline attentional advantage in near-hand space, unrelated to operations of shifting attention, called the attentional prioritisation account (Reed et al., 2006; see also Reed et al., 2010). To summarise, the attentional prioritisation account makes a very clear prediction: facilitation or enhancement for all visual tasks in near-hand space.

Reed et al. (2006, 2010) postulated that bimodal cells are the biological underpinning of attentional prioritisation in near-hand space. Bimodal cells are those which respond equivalently to both visual and tactile stimulation falling in their receptive fields. The receptive fields of these cells are hand-centred, meaning that they dynamically update according to the position of the hand in space. These cells have been identified in posterior parietal and premotor cortex in monkeys via single-cell recording (Graziano et al., 1994), and more recently identified in humans with functional magnetic resonance imaging (fMRI) (Brozzoli et al., 2012). According to Reed et al. (2006), bimodal cells are important for integrating visual and tactile information for spatial attention. To support this idea, these authors point out that nonpredictive visual cues can facilitate responses to tactile targets presented to the hand, and similarly that tactile cues near the hand facilitate responses to visual targets (Spence et al., 1998), and this depends on hand proximity not visibility (Kennett et al., 2002). Thus, according to Reed et al. (2006, 2010), bimodal cells are the biological basis for attentional prioritisation in near-hand space, which predicts enhancement for all visual-cognitive tasks.

2.2. Detailed-evaluation theory

Another attentional account of altered visual processing near the hands was suggested by Abrams et al. (2008), which appears to contradict the predictions from the attentional prioritisation account. This theory was motivated by Abrams et al.'s results on three classic attentional tasks: visual search, inhibition of return (IOR) in a cueing task, and the attentional blink (AB). Each of these results is discussed in detail below. These authors used what has become the more conventional hand proximity manipulation, in