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Slower attentional disengagement but faster perceptual processing near the hand

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ABSTRACT

Many recent studies have reported altered visual processing near the hands. However, there is no definitive agreement about the mechanisms responsible for this effect. One viewpoint is that the effect is predominantly attentional while others argue for the role of pre-attentive perceptual differences in the manifestation of the hand-proximity effect. However, in most of the studies pre-attentional and attentional effects have been conflated. We argue that it is important to dissociate the effect of hand proximity on perception and attention to better theorize and understand how visual processing is altered near the hands. We report two experiments using a visual search task where participants completed a visual search task with their hands either on the monitor or on their lap. When on the monitor, the target could appear near the hand or farther away. In experiment 1, a letter search task showed steeper search slope near the hand suggesting slower attentional disengagement. However, the intercept was smaller in the near hand condition suggesting faster perceptual processing. These results were also replicated in experiment 2 with a conjunction search task with target present and absent conditions and 4 set sizes. The results suggest that there are dissociable effects of hand proximity on perception and attention. Importantly, the pre-attentive advantage of hand proximity does not translate to attentional benefit, but a processing cost. The results of experiment 2 additionally indicate that the steeper slope does not arise from any spatial biases in how search proceeds, but an indicator of slower attentional processing near the hands. The results also suggest that the effect of hand proximity on attention is not spatially graded whereas its effect on perceptuo-motor processes seems to be.

1. Introduction

Most movements we make are not simply gestures in abstract space but interactions with the environment. Many of these interactions involve the use of objects or tools in the reachable space, for example, reaching to pick up a coffee cup or placing the hand on the mouse of a computer. The motor system is constantly informed about the environment's layout, with reference to the body, so that there is rapid synthesizing of motor and sensory information obtained from the environment (Gazzaniga, Ivry & Mangun, 2008), making these interactions more efficient. Neuro-physiological work done with non-human primates suggests that an interconnected network of at least four distinct regions in the brain- parietal area 7b, and ventral intraparietal area (VIP), F4 region of the inferior motor cortex and the putamen-is critical for the motor predictive mechanisms associated with these interactions (Matelli & Lupino, 2001; Rizzolatti, Fadiga, Fogassi & Gallese, 1997). These areas have neurons that are activated by both visual and tactile stimulations (referred to as the visuo-tactile bimodal neurons). Their activation is limited to the region of space immediately surrounding the body, often referred to as the Peripersonal Space (PPS). Rizzolatti et al. (1997) proposed that neurons in these areas bind visual information around the body and the tactile information from a specific body part, and are responsible for a body-part centred coding of visual stimuli falling in this space (Also see Fogassi et al. (1992); Fogassi et al. (1999); Graziano and Gross (1993); Graziano (2001) for similar findings). Brozzoli, Makin, Cardinali, Holmes and Farne (2012) reported a specific example of body-centric processing in the Ventral Intra Parietal area (VIP) of the brain. The VIP region has a constantly updating representation of the spatial relation between external objects and various positions of the hand when it moves. Such a representation has been suggested to act as a reference system for visuo-spatial processing (Fogassi et al., 1992; Graziano & Gross, 1993; Rizzolatti et al., 1997).

Behavioural evidence that supports these neurophysiological findings of hand centred-processing have been reported by many researchers (Abrams, Davoli, Du, Knapp & Paull, 2008; Cosman & Vecera, 2010; Gozli, West & Pratt, 2012; Makin, Holmes & Zohary, 2007; Reed, Grubb & Steele, 2006). Some of these effects have been regarded as

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attentional and others as pre-attentive or perceptual. For example, using an attentional cueing paradigm, Reed et al. (2006) showed behavioural evidence of attentional prioritization, in terms of faster orienting towards objects appearing in the peri-hand space as compared to those appearing farther away. More recently, they and others also showed the hand-proximity effect to be stronger on the side of the palm rather than the back of the hand (Reed, Betz, Garza & Roberts, 2010; Thomas, 2013), suggesting that the hand - proximity effect is also action-centred. Similarly, using a visual search task, Abrams et al. (2008) found a steeper search slope for finding targets in the visual space near the hands as compared with farther from the hands. Since steeper slopes indicate relative decrease in search efficiency, they concluded that hand proximity slows attentional disengagement. They also showed a reduction in inhibition (in IOR) as well as a larger Attentional Blink near the hands, supporting their claim of slower attentional disengagement.

On the other hand, many studies have examined how enhanced perceptual processing is altered near the hands. For example, Cosman and Vecera (2010) showed that the presence of hand modulates figure-ground segregation, a process understood to occur pre-attentively (Julesz, 1984; Kimchi & Peterson, 2008). Their participants more often reported the region of the stimulus near the hand as the figure, and the region of the stimulus far from the hand as the ground. Perceptual processing differences near the hands have been reported by other studies too. Tseng and Bridgeman (2011) showed improved accuracy in change detection when the hand was placed near the display. Similarly, Dufour and Touzalin (2008) reported improved accuracy for a speeded visual detection task in the presence of the hand.

In spite of a number of researchers reporting altered visual processing near the hands, there is no definitive agreement on the mechanisms underlying hand-proximity. One emerging idea that unifies these different findings is that objects near the hands are processed in-depth, leading to both a faster attentional orienting as well as slower attentional disengagement. Such an improvement in processing can also explain enhanced perceptual processing near the hands. Gozli et al. (2012) recently proposed the Modulated Visual Pathway (MVP) account to explain the hand-proximity effect. According to them, placing the hands in the visual field modulates the processing of the visual information through the action-oriented Magnocellular pathway, while placing it away modulates the processing through the perception-oriented Parvocellular pathway. The MVP account is primarily a pre-attentive account of hand-proximity effect and nicely unifies all the findings of altered perceptual processes near the hands. They can also explain the effects of hand proximity on attentional mechanisms in so far as faster pre-attentive processing results in more efficient attentional processing and vice-versa.

However, we believe that the attentional effect of hand-proximity is not as straight-forward as that. Theoretically, faster orienting and slower disengagement can both indicate in-depth processing and can co-exist. However, within a specific paradigm these will result in contradictory and confounding predictions about the data. For example, in visual search, enhanced attentional processing will predict shallower slopes indicating efficient search whereas slower disengagement will predict steeper slope indicating inefficient search.

This is not readily apparent as Reedet al. (2006) and Abrams et al. (2008) base their primary evidence on data obtained using different paradigms. That is, Reed et al. (2006) argued that the hand-proximity effect arises from an attentional prioritization of the space near, as they found faster orienting to targets appearing on the same side of the hand placed near the display as compared to the opposite side. On the other hand, Abrams et al. (2008) using a visual search task, found steeper search slopes in the presence of hands as compared to the condition in which the hands were placed on the lap.

According to Reed et al. (2006), their data shows attentional prioritization of objects that appear near the hand. However, as she correctly points out, the RT benefit near the hand occurs irrespective of cue validity. That is, target detection was faster near the hand for both validly and invalidly cued conditions. This does not support an attentional explanation. That is, in case of altered attentional processing near the hand, one would expect the hand proximity effect to be tied to the cueing effects. That is, both faster orienting and slower disengagement near the hands should result in an increase of the cueing benefit for targets that appear near the hands. It also seems that there are some issues with the interpretation of data. For example, Reed et al. (2006) concludes that the processing of objects nearer the hand is faster than objects farther away. However, the RT data reveals that, when comparing to their baseline no-hand condition, the effect of hand on attentional orienting is one of cost to the item appearing father away from the hand, without any apparent benefit to the target appearing near the hand. Moreover, compared to the control condition, there seems to be a performance cost for targets appearing far from the hand. Hence the argument about attentional enhancement does not seem to be supported by the data. First, there are no changes to the cueing effect in both near, far or control conditions. Second, the RT shows that the effect is one of generalised RT cost to targets appearing farther from the hand.

Indeed, the pattern of results found by Taylor and Witt (2014) fits with our reading of Reed et al. (2006). Using a posner cueing task (Posner & Cohen, 1984), they compared how the cueing effect is modulated by hand-proximity. They used either one or two hands to investigate hand-proximity effect, but also looked at how the effect is modulated by different object to hand relationships (no-hand, near-hand and on-the-hand). They found that the magnitude of cueing is the same for both no-hand and near-hand conditions. In addition, they also found a significant increase in cueing effect when the display was presented on the hand. Overall, it seems that the findings of Reed et al. (2006) can be re-interpreted to fit with the MVP account. That is, the general facilitation of RT for objects near the hand could be a pre-attentive effect of being processed by a faster M channel.

It is not clear from Abrams et al. (2008) study how the pre-attentive and attentional processes differentially affect the results. They report a display-size x hand-posture interaction which they interpret as a slope difference between hand-distal and hand-proximal conditions. However, their graph suggests a possible intercept difference between hand proximal and distal stimuli that is in the opposite direction of the slope effect. That is, there is a possible pre-attentive advantage for the hand-proximal search as the intercept seems to be smaller in that condition as compared to the hand-distal condition. However, neither the statistics for the main effect of hand proximity, nor an intercept analysis is reported. Thus, the possibility of a pre-attentive advantage for the hand-proximal target, along with slower disengagement is speculative at best. However, it is entirely possible as there are a large number of studies that show changes to pre-attentive processing in the presence of the hand.

According to Sternberg (1969), the search slope is an indicator of the attentional process as it reflects the time taken for the successive comparisons made between stimulus representation and the memory representation of the target stimulus for each item in the search array. A steeper search slope obtained for targets appearing near the hand would suggest the tendency to spend relatively higher time on items, in line with the slower attentional disengagement explanation given by Abrams et al. (2008). On the other hand, intercept gives a measure of factors other than attention influencing the search. It reflects the time to complete all the perceptuo-motor processes that occur before or after the successive comparisons made between stimulus representation and memory representation (Sternberg, 1969). Processes before the comparisons made could be visual processes (stimulus representation) prior to attentional selection, and processes after could be the decision and motor components coming after the search. Thus, any differences in intercept would suggest perceptuo-motor mechanisms, and not necessarily attentional mechanisms, getting affected near the hands. However, in the context of a large number of studies showing changes to the pre-attentive processing in the presence of the hand, there seems to be dissociable attentive and pre-attentive processes