Hand Position Affects Perceptual Grouping

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Abstract

Over the past decade evidence has accumulated showing that performance of attention, perception, and memory related tasks are influenced by placing the observer's hands near the stimuli. Two theories have been proposed to account for these effects. The attentional account holds performance is altered due to changed attentional prioritization of hands-proximal space, while the differential pathways hypothesis holds processing of stimuli near the hands is dominated by the magnocellular visual pathway resulting in the variety of documented effects. Here we test whether perceptual grouping processes are inhibited in hand-proximal space. Consistent with previous work on object-based attention, we find a benefit for the visual object in the hands-distal, but not the hands-proximal, condition suggesting perceptual grouping is impaired near the hands. This change in perceptual grouping processes cannot be explained solely by an attentional account of visual processing changes near the hands.
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1 Introduction

In recent years, evidence has accumulated indicating that visual processing of hand-proximal space differs from that of extrapersonal space in various tasks involving attention, perception, and memory. One proposed mechanism for these changes is the dynamic allocation of spatial attention is altered in hand-proximal space, possibly due to bimodal, visuotactile neuron recruitment for the processing space near the hands (Graziano & Gross, 1993). More recently, it has been suggested hand-proximal space is preferentially processed by the magnocellular (M) relative to the parvocellular (P) visual pathway (Gozli, West, & Pratt, 2012). Following a review of each of these theories, along with how past literature supports each of them, an experiment is reported which attempts to distinguish between these two accounts by determining if perceptual grouping is impaired near the hands – an effect not predicted by the attentional account. In the present paper, both theories will be reviewed, followed by a review of the existing studies and how each theory can, or cannot, account for the findings.

1.1 Alterations of spatial attention via bimodal neuron recruitment

The rationale for examining visual processes in hand-proximal space was rooted in evidence of bimodal, visuotactile neurons in the putamen, ventral intraparietal area (VIP), area 7b in the parietal lobe, and inferior area 6 of the premotor cortex (Graziano & Gross, 1993; for a review see: Graziano & Gross, 1998). The receptive fields of these neurons are somatotopically organized such that they respond to both visual and tactile information in respect to the body region they represent. In other words, the receptive field for a neuron representing the center of a hand will respond to stimuli in that area regardless of the hand’s positioning. The responses of these neurons are also graded as a function of stimulus distance displaying reduced activity as
viewing distance is increased. Notably, graded effects have also been found in human behavioral experiments dependent on hand distance from the target display (Adam, Bovend’Eerdt, van Dooren, Fischer, & Pratt, 2012; Reed, Grubb, & Steele, 2006). Additionally, if parietal regions are inhibited using transcranial magnetic stimulation, visual searches in peripersonal space are impaired while the opposite is the case if ventral brain regions are inhibited: visual searches extrapersonal space are slowed (Lane, Ball, Smith, Schenk, & Ellison, 2013). Note, that the Lane et al. study was not concerned with near hand space, but adds support for notion that peri- and extrapersonal space are represented differently and it may be due to those regions.

Given the role of bimodal neurons in spatial attention, Reed et al. (2006) speculated that completing spatial attention tasks in hand-proximal space should produce altered results to those observed in hand-distal space. In order to test their idea, Reed and colleagues (2006) had observers complete a covert spatial attention cueing paradigm using highly predictive cues (e.g. Posner & Cohen, 1984) with one of their hands placed near a target placeholder while they responded with the other hand using response keys placed on the desk. Consistent with changes in spatial attention and bimodal neuron recruitment, their results indicated near hand space is prioritized for processing, increasing the saliency of targets appearing in that space leading to more rapid responses to targets appearing there, regardless of which location was cued. In other words, regardless of which target location was cued, responses to targets near the hand were speeded. A weakened effect was seen if the hands were placed further from the placeholder and was not seen if boards were used as visual anchors. Interesting, fake hands did not influence response times, suggesting that the effect is unique to hands of the actor. These findings are consistent with known characteristics of bimodal neurons (Reed et al., 2006).
1.2 Differential biasing of visual pathways

Although the bimodal neuron hypothesis can account for the data from the spatial cueing experiment, there are alternative explanations of the effects of hand position on visual cognitive processing. Specifically, Gozli, West, and Pratt (2012) proposed that the altered visual processing in near hand space is a result of differential activation and inhibition of the M and P visual pathways. Physiologically, the M and P pathways diverge at least as early as retinal ganglion cells and, moving up from there, neurons in these two pathways differ in terms of their responsiveness across various dimensions including spatial and temporal acuity (Kaplan & Shapley, 1986; Livingstone & Hubel, 1988). Because objects appearing near the hands are likely targets of action and the M pathway largely projects to the dorsal, action stream (Goodale & Milner, 1992), Gozli et al. hypothesized that viewing stimuli in near hand space biases visual processing toward the M pathway while inhibiting P pathway processing. To test this hypothesis, they conducted two experiments to psychophysically assess visual and spatial acuity in hand-proximal and hand-distal space. M pathway neurons are known to be more sensitive temporally while P pathway neurons display higher spatial acuity (Livingstone & Hubel, 1988). If the M pathway dominates processing of stimuli near the hands, enhanced temporal acuity and reduced spatial acuity should be found in the hands-proximal condition while the opposite trade-off should be observed in the hands-distal condition. In the hand-proximal condition, higher d’ scores were found in the temporal acuity task along with lower d’ scores in the spatial acuity task. These results were consistent with their prediction suggesting hand position differentially affects the type of processing a stimuli receives through biasing the M and P pathways.

While the differential biasing of pathways and bimodal hypotheses provide different mechanisms as explanation for the changes in vision near the hands, it may be possible to integrate them. That is, the VIP, an area known to contain bimodal visual-tactile neurons, is
largely subserved by M pathway neurons and, further, the VIP is highly interconnected with the precentral gyrus, an area known to be modulated by the premotor cortex (inferior area 6); another area known to contain visual-tactile neurons (Graziano & Gross, 1993; Graziano & Cooke, 2006; Lewis & Van Essen, 2000). Additionally, the dorsal visual stream is largely composed of M pathway projections and is thought to facilitate action (Goodale, 1993; Goodale, 2011), and thus is likely to interact with other motor areas containing bimodal neurons such as the putamen and area 7b of the parietal lobe. Therefore, it may be possible the recruitment of visuotactile neurons in those regions is part of a broader activation of the M pathway leading to various processing changes including how space is prioritized for processing. As will be discussed below, however, other behavioral results which not as easily accommodated into the bimodal account for near hand effects in vision.

1.3 Literature Review

Much of the work in this area has been designed and interpreted in terms of variations in spatial attention due to the additional recruitment of bimodal neurons. In that light, Abrams and colleagues compared performances for both hand-proximal and hand-distal conditions on visual search, covert spatial cueing and attentional blink tasks (Abrams, Davoli, Du, Knapp, & Paull, 2008). On the visual search task, steeper search slopes are evident in near hand space. That is, as the number of items in the search increased the time to complete the search increased at a greater rate in the hands-proximal relative to the hands-distal condition. In the inhibition of return task, the magnitude of response inhibition was significantly smaller in the hand-proximal condition. Lastly, attentional blink length increased when completing the task in near hand space. These results were interpreted as impaired attentional disengagement from targets resulting in the slower search times (latency increase for between switching targets results in longer response times), smaller inhibition of return magnitudes (attention had yet to fully disengage from the
location after the original cue such that quicker responses were possible), and longer attentional blinks (increased time to disengage from the first target leading to a longer lag before processing another item). In a subsequent study using a global/local task, slowed latencies are found for switching between global and local scopes of attention, consistent with slowed temporal dynamics of spatial attention found previously (Davoli, Brockmole, Du, & Abrams, 2012). Overall, these data are consistent with the hypothesis that attentional orienting is altered in hand-proximal space.

Continued examination of attention in hand-proximal space has looked at how well distracting stimuli are ignored in that space. For example, placing hands between the target and flankers appears to create an attentional “shield” reducing flanker-target interference (Davoli & Brockmole, 2012). While these results are easily accountable by the recruitment of bimodal neurons representing the hands (resulting in increased salience of the space between the hands and, therefore, speeded responses), the results are difficult to evaluate as no control condition whereby the hands were placed so that the flankers and target appeared between them was included. In other words, it may not be the case that the hands act as a shield constraining attention, but rather flankers exhibit a lessened effect in near hand space in general. Indeed, in a more recent study, reduced flanker interference was found for stimuli appearing between the hands in general, although this in itself does not exclude the possibility that hands shield attention as well (Weidler & Abrams, 2013). Taken together, there is strong evidence of changed attentional processing when viewing stimuli in near hand space and may be accounted for by the additional recruitment of attentional resources via bimodal neurons.

Further research has shown changes beyond attention tasks. In a study of semantic processing, observers were shown sentences that were either semantically coherent or incoherent and asked to discriminate which category the target sentence belonged (Davoli, Du, Montana,
Garverick, & Abrams, 2010). That is, they were shown sentences that were valid in terms of grammar, but may or may not have made sense semantically, and were asked to respond whether they were sensible or nonsensical. Here, observers were significantly worse in the hands-proximal condition; a counterintuitive finding considering it is commonplace to hold reading materials and many people seem to prefer that method of reading. These findings were explained as a trade-off between semantic and spatial processing, though the trade-off behind such a trade-off are unclear. A more recent study, however, may shed some light on these perplexing results. Thomas (2013) compared performance of visual tasks with subjects using a power versus a pincer grip and found significant changes in behavioral performance. Namely, the speeded RTs to target onsets were observed only in the power grip condition leaving open the possibility that more detail oriented processing occurs within in a pincer compared to a power grip. Therefore, it may be that the power grip posture used in the Davoli et al. (2010) was inadequate for producing near hand benefits in reading, though this speculation at this point and further work is warranted.

Tseng and Bridgman (2011) have examined performance on working memory tasks as a function of hand position, and again significant effects were found. Using a change detection task, observers were found to be more accurate and were able to hold more items in visual working memory in the hands-proximal condition. Interestingly, when viewers were asked to complete the same task with only one hand near the monitor, facilitated performance was only found for the right hand and, even then, it was weaker than both hands together. This finding may be explained by a form of overlearning: people in a right handed population rarely act in their environment solely with their left hand, but commonly do with only their right or both hands. Furthermore, the near hands benefit was distributed evenly across the screen. The researchers here were careful to indicate, however, that the changes of performance in their task
are likely not changes in working memory explicitly, but more likely a change in processing at earlier areas in the visual pathway and perhaps rooted in attention.

Given that much of the information people take in on a daily basis is through something we are holding and reading, it is also possible that learning processes are changed in near versus far hand space. To test this possibility, observers completed a contextual cueing task in which stimulus specific or stimulus general characteristics could be varied (Davoli, Brockmole, & Goujon, 2012). Here, the researchers hypothesized that stimulus specific information (such as spatial arrangement) would effectively be used in near hand space while the use of stimulus general characteristics (such as color changes) would be inhibited due to reduced generalization and abstraction of information near the hands. In both experiments of that study, participants were shown full color, fractal image patterns and asked to identify a small ‘T’ within the images. Within a given block of trials, half of the images would repeated while the other half were novel with the idea being the ‘T’ will be found faster in repeat images. In experiment one of that study, the images were repeated exactly in every detail across trials and, as expected, the ‘T’ was found faster in images which were repeated across time with the facilitation effect becoming greater with increased viewings. In experiment two, however, the structure of the images repeated, but the color patterns changed across viewings. In this case, in which structural information had to be abstracted across various colors of the same image, a cueing effect was observed in the hands-distal condition, but not the hands-proximal condition. This finding suggests a trade-off in hands-proximal space with enhanced detail oriented processing, but with a detriment in utilizing stimulus general details.

Perceptual processing also seems to be sensitive to hand position. In a study of the pre-attentive process of figure-ground segmentation (Kimchi & Peterson, 2008), researchers observed that image regions appearing near the hands were more likely to be identified as figure
regardless of the image based information typically used to make such discriminations (Cosman & Vecera, 2010). Additionally, in another study, object identification efficiency was differentially affected by hand position based on whether the images contained high (HSF) or low spatial frequency (LSF) information whereby LSF are more quickly, and equally as accurately, identified in the hand-proximal condition (Chan, Peterson, Barense, & Pratt, 2013). While changes in figure-ground assessment are easily accommodated by both theories, changes in object perception are more readily explained by the biased visual pathways framework. The M pathway neurons are known to be sensitive to low spatial frequency stimuli (Wiesel & Hubel, 1966) and, further, the M pathway is thought to support top-down object recognition through rapidly sending the objects “gist” information to the orbitofrontal cortex (Kveraga, Boshyan, & Bar, 2007). Therefore, the observed speeded responses to LSF near the hands is consistent with increased M pathway processing for that space and possibly may result enhanced recognition of near hand objects due to their potential for action. More experimentation, however, will be needed before definitive conclusions are possible.

Where do the bimodal and differential pathways accounts stand in terms of explaining these results? The bimodal account has been successful in explaining many of the above studies results through attributing changes in spatial attention when viewing hand-proximal space via the additional processing resources of the visuotactile neurons. It follows that impeded attentional disengagement (Abrams et al., 2008; Davoli et al., 2012; Davoli & Brockmole, 2012) might be a result of visuotactile neurons in motor areas representing the hand, because it might facilitate actions toward selected objects through inhibiting attention from switching to new, potentially distracting, objects. Hand-proximal changes in working memory (Tseng & Bridgeman, 2011), figure-ground segmentation (Cosman & Vecera, 2010), pattern learning (Davoli, Brockmole, & Goujon, 2012), and reading (Davoli et al., 2010) have similarly been explained in terms of the
type or depth of processing stimuli receive as a result of bimodal neural recruitment. Additionally, researchers have noted that visual acuity for stimuli appearing on the hand is dependent upon the tactile acuity of the given hand region (Brown, Morrissey, & Goodale, 2009). That is, visual acuity is higher for stimuli appearing on the ventral rather than the dorsal surface of the hand suggesting the smaller tactile receptive fields found on the ventral surface of the hand are reflected in visual representations of stimuli appearing there, possibly due to bimodal representations of that area. As noted above, however, the biased visual pathway hypothesis does not necessarily preclude bimodal neural recruitment given that areas known to contain those neurons are contained within the M pathway and it may be the biased visual pathways hypothesis more readily accounts for certain findings.

Given its recency, few studies have explicitly tested the M/P pathway hypothesis, but some observations may be made. Accounting for the observed spatial-temporal acuity trade-off near the hands (Gozli et al., 2012) is difficult using the bimodal account. Further, other previous findings may be more easily explained with the differential pathways approach. For example, the M pathway’s low spatial resolution may account for observed detriments on semantic and other tasks requiring fine perceptual acuity. That areas near the hands are more readily determined to be the figure of an image is also well accounted for given M pathway supports figure-ground assessment (Livingstone & Hubel, 1988). Consistent with increased M pathway involvement in processing hand-proximal stimuli, a reduction in object substitution masking (OSM) magnitude has been observed near the hands, thought to be a result of an improved ability to segregate the object and mask due to the enhanced temporal precision offered the M pathway (Goodhew, Gozli, Ferber, & Pratt, 2013). Recently, Abrams and Weidler (2014) conducted an experiment that supported the M pathways role in processing space near the hands. By saturating the M pathway with diffuse red backgrounds (Livingstone & Hubel, 1988; West et al., 2010; Wiesel &
Hubel, 1966), performance changes on visual search and spatial sensitivity tasks due to hand proximity were eliminated, consistent with expectations concerning the M pathway’s role in processing near hand space. Also consistent with the differential visual pathways account, feature binding, a P pathway dependent process (Barense, Gaffan, & Graham, 2007), has been shown to be impaired in in hands-proximal space (Goodhew, Fogel, & Pratt, 2014; Gozli, Ardron, & Pratt, 2014; Kelly & Brockmole, 2014) suggesting hands-proximal viewing leads to inhibited P pathway processing. These findings are consistent with differentially biased pathways hypothesis in that, if M pathway processing is facilitated, an inhibition of the P pathway is expected (Yeshurun, 2004).

1.4 Current experiment

The current study examined gestalt grouping processes in hand-proximal and hand-distal space with a paradigm which offers competing predictions for attention and visual pathway biasing based accounts of hand proximal vision effects. Specifically, we take advantage of the gestalt principle of 'good continuation' to produce displays of lines which contain both a gestalt-formed object and a non-object (i.e., a group of lines). It has previously been shown that such gestalt-formed objects will capture attention, as targets appearing within such objects are responded to more rapidly than those within the non-objects (Kimchi, Yeshurun, & Cohen-Savranski, 2007). Here, we employ a similar paradigm to the object-based cueing paradigm of Kimchi et al. which offers contrasting predictions for the attention and visual pathway biasing accounts of hand-proximal effects.

The key to the biased-pathway account is that grouping items into a unified object is a ventral stream process (Doniger et al., 2000; Han, Ding, & Song, 2002) which receives its primary input from the P pathway (Livingstone & Hubel, 1988). Thus, if hands-proximal effects are driven primarily through biasing processing toward the M pathway while inhibiting the P
pathway, then an absent or weakened object-based cueing effect should be found in the hands-proximal condition because the inhibited P pathway would yield weaker gestalt grouping effects. The attentional account, however, predicts that object-based cueing effects will be found in both the hands-proximal and hands-distal condition. Crucially, the predictions made by each account are incompatible with the alternative account. Finding equivalent object-based cueing effects in both hand spaces would be difficult to explain with P pathway inhibition while a much weakened cueing-effect in hands-proximal space over hands-distal space cannot be explained by modulations of attention alone.

2 Method

2.1 Participants

Seventeen undergraduates attending University of Toronto participated in the experiment and were compensated with course credit. All participants reported normal or corrected to normal vision and provided written informed consent.

2.2 Materials and apparatus

Stimuli were generated and presented using the psychophysics toolbox libraries (Brainard, 1997; Pelli, 1997; version 3.0.8) for Matlab (MathWorks, Natick, MA) on a CRT monitor with a screen resolution of 1080 X 768 and a refresh rate of 85 Hz. A modified mouse was attached to each side of the monitor for collecting data in the hand-proximal condition. Viewing distance was kept constant at 45 cm using a chinrest for the duration of the experiment.

Stimuli were presented in white on a black background, and consisted of an array of 7 curved lines each of which was a 70° arc of a 4° visual angle diameter circle (see Figure 1). One curved line was placed at the centre with its convex/concave portions along the horizontal meridian. The remaining 6 lines were placed on each side of the centre line, three on each side.
On one side, the lines were oriented such that, along with the centre line, the four lines create a circular object while the other three lines appeared in mirrored positions on the opposite portion of the display and reversed so that the concave side faced outward. After a delay of 100-300 ms, the target line changed colour to red or green.

2.3 Procedure

The experiment was completed in two blocks. In one block, participants responded with both hands on a keyboard on the desk in front of them (hands-distal) and in the other condition they responded with both hands on computer mice attached to the monitor (hands-proximal) in order to ensure the entire display was in the hands’ action space or none of it was. Each trial began with a central fixation cross. After 1000 ms, an array of white lines appeared. Following a variable delay (100, 200, or 300 ms) to add temporal uncertainty, one line changed colour to red or green. Any line except for the centre line could be the target. Participants were instructed to respond as quickly as possible, without sacrificing accuracy. A left-hand response was required if the target was green, and a right-hand response if the target was red. In the hands-distal condition, left and right handed responses were made with the ‘Z’ and ‘/’ keys, respectively. In the hands-proximal condition, left and right responses were made by clicking the corresponding computer mice attached the sides of the monitor.
2.4 Design

The two blocks, hands-distal and hands-proximal, were counterbalanced across participants. Trials were randomized across target location, target type (within object vs. outside object), SOA, and target colour. Each combination of factors was repeated 5 times for a total of 360 trials per block such that participants completed a total 720 trials in the testing session.

3 Results

Trials with incorrect responses, RTs faster than 100 ms, and RTs slower than 1000 ms were excluded as response errors, anticipatory responses, and attentional lapses, respectively. The mean and standard deviation of the remaining RTs were calculated and all trials with RTs more than 2 standard deviations above the mean were excluded.
Overall, mean accuracy was 95\% (SD = 3.8\%) with no individuals performing below 89\%. A repeated measures, 2 (distal and proximal hand placement) X 3 (100, 200, and 300 ms SOA) X 2 (object or non-object target location ANOVA was conducted with RTs as the dependent measure. The ANOVA revealed a main effect of hand position, $F(1,16)=5.36, p < .05$, partial $\eta^2 = .251$, with a 15-ms ($SE = 7.29$) benefit for the hands-proximal compared to the hands-distal condition. There was also a main effect of SOA, $F(2,32) = 16.41, p < .05$, partial $\eta^2 = .503$, with a slower mean RT at the 100 ms SOA compared to the 200 and 300 ms SOAs, $t(16) = 3.65, p < .05$; $t(16) = 4.627, p < .05$. RTs did not differ between the 200 and 300 ms SOAs, $t(16) = .281, p > .05$.

Figure 2: Response times by object type at each hand position and SOA. Only in the hands-distal, 100 ms SOA condition is there a significant object based cueing effect. Error bars represent $SE$s.

A 3-way interaction was found between hand position, SOA, and target type, $F(2,32) = 3.55, p < .05$, partial $\eta^2 = .182$. Paired samples t-tests were conducted comparing the effect of target type at each SOA. Consistent with previous work object-based advantage (Kimchi et al.,
In the hands-distal condition and at 100-ms SOA, responses were faster to targets appearing on the gestalt figure compared to non-gestalt items, $t(16) = 2.16$, $p < .05$. There was no effect of target type at the other SOAs ($p > 0.05$). In the hands-proximal condition, no differences due to target type were found at any SOA ($p > 0.05$, see Figure 2). To test whether the lack of a cueing in the hands-proximal condition was due to a RT floor effect the variability of RTs within each of the hands conditions was compared with no significant different found, $t(16) = .125$, $p > .05$.

Finally, a 3-way, repeated measures ANOVA with error rate as the dependent measure was conducted. No main effects or interactions were significant indicating there was not a speed-accuracy trade-off driving the faster RTs found for targets appearing in objects.

### 4 Discussion

In this experiment, we investigated whether perceptual grouping processes were impaired or not in hand-proximal space. It was found that, in the hands-distal condition, targets appearing within a gestalt-formed object were responded to reliably faster relative to targets appearing outside the gestalt at 100-ms SOA. However, in the hands-proximal condition, whether or not the target appeared within the gestalt-formed object had no effect on RTs across the SOAs. Thus, the data indicate that gestalt grouping processes are indeed disrupted when viewing stimuli in hand-proximal space.

Because the object was a non-predictive cue of target location, our hands-distal finding replicates previous work showing gestalt-formed objects can exogenously cue attention (Kimchi et al., 2007). It is worth noting that Kimchi et al. found their largest effects at their shortest SOA, and similarly we observed an object-based benefit only with our shortest SOA (100 ms). They also found small effects at SOAs up to 500 ms, whereas we did not, although our findings are more in line with the typical time course of stimulus-driven attentional capture whereby
facilitation at cued locations tends to dissipate with SOAs over ~150 ms (e.g., McAuliffe & Pratt, 2005, Posner & Cohen, 1984; Theeuwes, Atchley, & Kramer, 2000). Also, participants in the study by Kimchi et al. had to a) read a word (e.g., “above”) on every trial, and b) attend to an asterisk that, together with the word, defined the target location. Thus, being required to read words (which involves grouping letters into a unit), as well as using the informative cues to locate each target, may have encouraged forming a representation of the spatial layout that preserved the benefit of the gestalt figure. By contrast, our visual target was defined as a temporally unique colour-singleton and no other kinds of gestalt (e.g., words) or informative cue was used. For these reasons, we believe the benefit of the gestalt figure in the present study reflected a purely stimulus-driven bias and, as such, it was short-lived.

Given neurological evidence that perceptual closure is supported by P pathway processes (Doniger et al., 2000; Han et al., 2002), the lack of object-based cueing effects in the hands-proximal condition is consistent with the idea P-pathway processing is inhibited when viewing stimuli in hand-proximal space. That is, the current data suggest P pathway processing is inhibited in when processing stimuli in hand-proximal space weakening gestalt grouping processes such that the gestalt-formed object did not captured attention. Furthermore, these data are consistent with recent findings of other ventrally controlled perceptual processes being impaired near the hands (Goodhew, Fogel, et al., 2014; Gozli et al., 2014; Kelly & Brockmole, 2014). The main effect of hands in the present study is also consistent with the processing characteristics of the M pathway, namely M-dominant processing would a) be less prone to the cost of representing of irrelevant visual features (Ganel & Goodale, 2003; Gozli et al., 2014), and b) have a relatively rapid rate of information intake (Chan et al., 2013). Of course, such an overall benefit of hand-proximity is not consistently obtained in the literature, and may very well be restricted to certain types of visual stimuli (e.g., Abrams et al., 2008; Gozli et al., 2012).
While the differential pathways hypothesis can accommodate the current findings, can attentional accounts do so as well? The main effect of hand condition, with overall shorter latencies in the hand-distal condition than the hand-proximal condition, is consistent with recruitment of bimodal neurons for processing hand-proximal space and Reed et al.'s (2006) finding of faster responses to targets appear near the hands. Nonetheless, although an attentional account can predict the main effect of hands, it unclear how it could explain the lack of object-based cueing effects in hand-proximal space. For example, the attentional account suggests hand-proximal stimuli undergo deeper processing resulting in delayed disengagement from items which initial capture attention. Thus, in the current experiment, if gestalt grouping processes were unaffected by the hands manipulation (as attentional accounts have no reason to suggest they would be), one would still predict the gestalt-formed object would capture attention and produce an object-based cueing in hand-proximal space, but that the effect would be found across extended SOAs relative to the hands-distal condition because of delayed attentional disengagement from the object.

While an attentional account of hands-proximal effects is cannot adequately explain the current results, does it remain necessary to explain other hand proximity effects? For example, Abrams et al. (2008) found altered effects in hands-proximal relative to hands-distal conditions on a visual search, spatial cueing and attentional blink tasks which are all regarded as attention tasks. However, it is important to acknowledge that while these tasks are traditionally thought of as attention based tasks, any alternations in performance on such tasks do not necessary indicate changes in attention. For example, on the visual search task steeper search slopes were found in the hands-proximal condition indicating observers were spending longer investigating each target before continuing the search. This finding was interpreted as delayed attentional disengagement from each target allowing for deeper processing of hands-proximal stimuli which are potentially
relevant for immediate action. However, given the relatively low spatial resolution in hands-proximal space, it is possible that more time was necessary to identify each letter before moving on to the next target. A similar explanation could be given for the increased attentional blink magnitude near the hands since the task was again letter identification. The last experiment in that study was a cueing experiment examining IOR in hand-proximal space. However, these results, and those of Reed et al. (2006), are difficult to interpret because they rest on the untested assumption that RTs to onset transients (without any cues presented) are equal in both hands conditions. This seems like an especially tenuous assumption if hand-proximal visual processing is dominated by the highly luminance sensitive and action oriented M pathway. Without an appropriate baseline against which to evaluate the RTs from cueing experiment, it is hard to make strong conclusions from cueing experiment data. In another task reporting an attentional effect, Davoli et al. (2012) showed higher costs when switching between global and local scopes of attention. Rather than a cost in switching between different scopes of attention, the costs observed may have been caused by costs in grouping local elements into a global element and/or lower spatial acuity in hand-proximal space leading to costs associated with individuating the local items. In all, these “attention” studies do not convincing necessitate the inclusion of an attentional mechanism for explaining hands-proximal effects.

Similarly, other studies, which did not use explicitly attention-based tasks have used attention as an explanatory mechanism for their effects. For example, Davoli et al. (2010) reported a trade-off between and spatial and semantic processing near the hands. The effects can also be explained, however, within the differential pathways framework. In experiment one, subjects were observed to make more errors in categorizing sentences as sensible or nonsensical in the hands-proximal condition while in experiments two and three reduced Stroop interference was found near the hands. Both of these effects were initially interpreted as reduced semantic
processing manifesting in the higher error rates on the reading tasks and reduced interference on the Stroop task (the word was less readily processed such that there was less interference with the color). Given there is no obvious mechanism that would drive such a reduction in semantic processing, however, another explanation is necessary. One possibility is the increased error rates on the reading task were due to the reduced spatial acuity found by Gozli et al. (2012). Likewise, since feature binding is impaired in hand-proximal space (Goodhew, Fogel, & Pratt, 2014; Gozli et al., 2014; Kelly & Brockmole, 2014) and feature binding is a P pathway process (Barense et al., 2007) and the M pathway is better able to ignore task irrelevant information (Ganel & Goodale, 2003), the performance on the Stroop task may be better explained by A) reduced binding of the color and word information and B) enhanced ability to ignore the task irrelevant feature such that reduced inference is observed. Consistent with the idea of feature specific processing in hand-proximal space, Davoli et al. (2012) reported reduced visual learning when the task required abstracting information across many displays suggesting hand-proximal vision is biased toward specific features, consistent with attributes of the M pathway.

In conclusion, the present data offers support for the differential contribution of M and P pathways hypothesis when viewing hand-proximal stimuli. Although the hypothesis of changes in spatial attention via bimodal neuron can account for the main effect of hands, it cannot account for the lack of object based facilitation near the hands. M pathway dominate processing (along with P pathway inhibition) accounts for both these effects. In conjunction with the existing literature, the present findings add to the emerging picture that hand position and object perception, ranging across gestalt grouping, object consistency, object files, and rapid gist identification, are intimately connected to each other. Lastly, while the differentially biased visual pathways hypothesis does not exclude alterations of attention as contributing to hands-proximal changes in vision, no studies to date have convincingly demonstrated such an
attentional mechanism is necessary. Rather, a critical review of past studies suggest they can either be more parsimoniously explained by the differential pathways hypothesis or, in light of more recent studies, appear to be flawed methodologically such that interpretations of them are troublesome.
References


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