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ORIGINAL RESEARCH REPORT

Situational Determinants of Hand-Proximity Effects

Tony Thomas and Meera Mary Sunny

Recent studies have demonstrated altered visual processing of stimuli in the proximal region of the hand. It has been challenging to characterize the range and nature of these processing differences. In our attempt to deconstruct the factors giving rise to the Hand-Proximity Effects (HPEs), we manipulated the organization of items in a visual search display. In two experiments, we observed the absence of HPE. Specifically, in Experiment 1, we presented the search display in only one half of the monitor (split diagonally), which could be either near or far from the hand placed on the corner of the monitor. The results of a Bayesian analysis showed that the search efficiency was not significantly different for neither 'near' nor 'far' condition when compared with the baseline condition in which the hand rested on the lap. In Experiment 2, the search display was arranged horizontally across the monitor. A Bayesian analysis showed that RTs did not vary depending on the proximity of the target to the hand as well as the baseline (lap) condition. The present results characterize features of the HPE that have not been reported previously and are in line with recent reports of the failure to replicate HPE under various circumstances.

Keywords: hand-proximity; visual search; attentional disengagement; spatial prioritization; altered vision near hands

1 Introduction

While previous studies have reported altered visual processing of objects placed close to the hands, the nature of these differences are highly debated (Abrams, Davoli, Du, Knapp & Paull, 2008; Cosman & Vecera, 2010; Gozli, West & Pratt, 2012; Makin, Holmes & Zohary, 2007; Reed, Grubb & Steele, 2006). A variety of perceptual, attentional and working memory paradigms have been used to explore these processing differences in the proximal region of the hand. For example, using an attentional cueing paradigm, Reed et al., (2006) claimed that there is faster attentional orienting towards objects appearing in the peri-hand space. Similarly, Valdés-Conroy, Sebastian, Hinojosa, Roman, and Santaniello (2014) reported responses to be faster towards objects located in the near-space compared to objects in the far-space. Findings using ERP supported this result by showing a consistent N1 visual component with faster latencies and larger amplitudes for objects in near space.

In contrast, Abrams et al., (2008) reported a relatively steeper search slope for finding targets in a visual search task when participants kept their hands near the display as compared to the lap. Since steeper search slopes indicate relatively inefficient search, they concluded that hand proximity slows attentional disengagement. They further substantiated this claim by showing a reduction in the magnitude of Inhibition of Return (IOR) as well as increased Attentional Blink near the hands. Attentional disengagement is thought to be critical for both of these processes (Klein, 2000; Taylor & Klein, 1998). Recently, Thomas and Sunny (2017) suggested that the co-occurrence of faster pre-attentive and slower attentional processes in the proximity of the hand could explain these contradictory findings.

Additionally, many studies have shown enhanced perceptual processing in the near regions of 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). In their study, participants more often reported the region of the stimulus nearer to the hand as the figure, and the region of the stimulus farther from the hand as ground. Similarly, Tseng and Bridgeman (2011) showed improved accuracy in change detection when both the hands were placed near the display compared to a baseline no-hand condition. Similarly, Dufour and Touzalin (2008) reported improved accuracy for a speeded visual detection task in the presence of the hand. Taken together, these studies suggest that objects near the hands are processed in-depth, leading to both a faster attentional orienting as well as slower attentional disengagement (Thomas & Sunny, 2017; Reed et al., 2010).

The Modulated Visual Pathway (MVP) account (Gozli et al., 2012) provides a relatively comprehensive framework for understanding HPE and explains most

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of the conflicting empirical findings. According to MVP, merely placing the hands in the visual field modulates the processing of visual information through the action-oriented magnocellular pathway, and away from the perception-oriented parvocellular pathway. Gozli et al., (2012) found that in the presence of hand, detection of temporal discontinuities – a magnocellular process- was enhanced, whereas the detection of spatial discontinuities – a parvocellular process- was diminished when compared to a baseline no-hand condition. The opposite pattern of enhanced detection of spatial discontinuities was found in the no-hand condition compared to the hand-present condition. Moreover, Kelly and Brockmole (2014) reported enhanced visual working memory for orientation, at the cost of memory for color information, for objects presented near the hands. They also found the converse pattern in the far region of the hands; a better recall for color information, at the cost of orientation information, supporting the MVP hypothesis.

However, there is another set of findings which suggest that the re-allocation of resources between the Magnocellular and Parvocellular pathways does not fully explain modulation of visual processing near the hands (Garza, Strom, Wright, Roberts & Reed, 2013; Schultheis & Carlson, 2013; Andringa, Boot, Roque & Ponnaluri, 2018; Dosso & Kingstone, 2018; Noel, Serino & Wallace, 2018). For instance, the study by Noel et al., (2018) looked at whether multisensory (versus unisensory) processing varies as a function of stimulus-observer distance. They failed to find evidence for enhanced audio-visual processing in near space relative to the far space. Moreover, they found the overall strength of the neural responses across the entire electrode montage to be stronger for the stimuli presented at the boundary of the peripersonal space, as compared to the stimuli presented far from the boundary. The finding was in contrast with previous results that suggested enhanced visuo-tactile and audio-tactile processing within, as opposed to at the border of the peripersonal space (e.g., Serino et al., 2017; Spence, Pavani, & Driver, 2004; Spence, Pavani, Maravita, et al., 2004). Another study by Garza, et al., (2013) showed that even when the location and proximity of the hand to the target remains constant across conditions, the hand proximity effect changes depending on the functional priority of the hand in the experimental context.

Similarly, Schultheis and Carlson (2013) highlighted the number of postures to be an essential factor in replicating the effects found by Abrams et al., (2008). In a series of experiments, Schultheis & Carlson (2013) found that the hand-proximity effects could not be replicated in experimental conditions having more than two hand postures. That is, they could reproduce the basic effect that Abrams et al., (2008) showed using just two hand postures (proximal and distal). The addition of one more posture- the release posture- where participants were instructed to release the response buttons to respond to target instead of pressing them- eliminated the earlier observed effect across the proximal and the distal (lap) conditions, demonstrating the circumstances when hand-proximity effects are not observed. Therefore, situational determinants such as the number of postures seem to play a role in determining the presence or absence of the hand effects. These findings are in line with other recent studies that suggest that the hand-proximity effects are fragile (Andringa, Boot, Roque & Ponnaluri, 2018; Dosso & Kingstone, 2018).

2 Experiment 1

2.1 Introduction

Thomas and Sunny (2017) showed that hand proximity effects are sensitive to the distance of the target from the hand not just to its absence or presence in the visual field. However, it was not clear whether the effect of distance reflects changes in attentional priority with objects closer to the hands being prioritized relative to objects farther away. This was tested in the first experiment, where the participants were presented with a search array that appeared only in one half of the monitor (split diagonally), unlike a typical (full-display) visual search task. They completed the search task with either their hand placed at each corner of the monitor as instructed or on the lap. The partial display of the search array ensured that the search array appeared either near or relatively far from the hand when positioned at that corner of the screen.

If we observe HPE even when the search space is restricted to locations near or far away from the hand, it would suggest a strong spatial bias that does not depend on the presence or absence of objects. If not, then it supports the notion that HPE is due to prioritization of objects closer to the hand relative to objects farther away from the hand.

2.2 Method

2.2.1 Participants

16 students from IIT Gandhinagar were paid to participate in the experiment (9 males and 7 females; mean age- 24 years). All the participants were right-handed and had normal or corrected-to-normal vision. All experimental, as well as data management protocols, were approved by the Technical Committee of the IITGN Institutional Ethics Committee (IEC). Experimental design and data collection was conducted in accordance with the guidelines and regulations of the IEC. Informed consent was obtained from all participants before the study began.

2.2.2 Apparatus and stimuli

The stimuli were presented on an 18-inch monitor (1440 × 900 resolution), controlled by an IBM PC compatible computer. Responses were collected on a standard keyboard. Letters, each 0.7 cm high (0.72°) and 0.6 cm wide (0.62°) at a distance of 55 cm and white in color, were presented on a black background. The stimulus consisted of a fixation cross and letters. The display consisted of 'E' or 'F', along with 'H', 'L', 'M', 'N', 'P' and 'Z'. Participants were seated in a dimly lit cubicle with their dominant hand resting on the left and right arrow keys of a standard QWERTY key board and were used to make the responses to the experimental task. A platform was arranged such that it supported their non-dominant hand to easily rest on any of the four corners of the computer monitor with ease, when required.

2.2.3 Design and Procedure

At the beginning of each trial, a white fixation-cross appeared for 1s at the centre of the display. A search array followed the fixation cross and consisted of 4 or 7 letters. The participants were asked to look for a target letter 'E' or 'F' among the other letters and respond as fast as they can while keeping the errors to a minimum.

The responses were made using their dominant hand by pressing the left arrow key if the target was 'E' and right arrow key if the target was an 'F'. This key allocation was counter-balanced across participants. Feedback was given for every incorrect response by displaying the message "Incorrect response. Press any key to continue" and the experiment resumed only after a key press was made. In case of correct response, the next trial started automatically after the response. Participants completed the search task in two hand conditions – while they rested the index finger of their non-dominant hand against a corner of the monitor (hand condition; see **Figure 1**) or kept their hand relaxed on their lap (no-hand condition; see **Figure 2**).

In the hand condition, the search array was equally likely to appear in the near or far region. The search items could appear only in the 'near' region of space of the index finger positioned at each corner of the display (i.e., within the area of an arc with a radius of 15 cm from the corner; See **Figure 3**), or in the area beyond ('far'; See **Figure 4**). Therefore, the targets were classified into 'near' or 'far' depending on its distance from whichever corner the participants kept their index finger.

The participants completed the hand condition placed at all four corners of the monitor, blocked trial-wise. In each corner, they completed 100 trials each, which consisted of equal number of trials in two set-sizes (4 & 7) and target distances ('near' & 'far'). The information about hand-quadrant was not used in the analysis. In the 'no-hand' condition they completed 100 trials of the same visual search task in two set-sizes. The order in which the participants completed the 'hand' and 'no-hand' conditions were also counterbalanced across participants.

Figure 1: Illustration of the 'Hand condition', where participants rested their non-responding hand at each corner of the monitor in such a way that the index finger touched the corner in a pointing gesture. In the example used, the hand is placed at the upper-left corner of the display.

Figure 2: Illustration of the 'No-hand condition', where participants rested their non-responding hand on the lap.

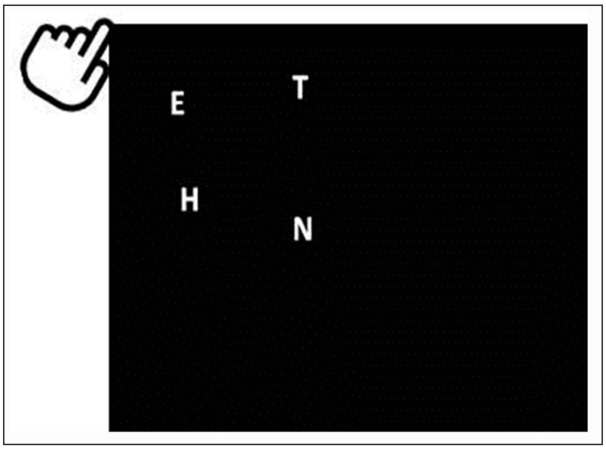

Figure 3: Example display of when the search array appears only in the near, and not in the far region of space of the hand when placed at the upper-left corner of the screen, for set size 4.

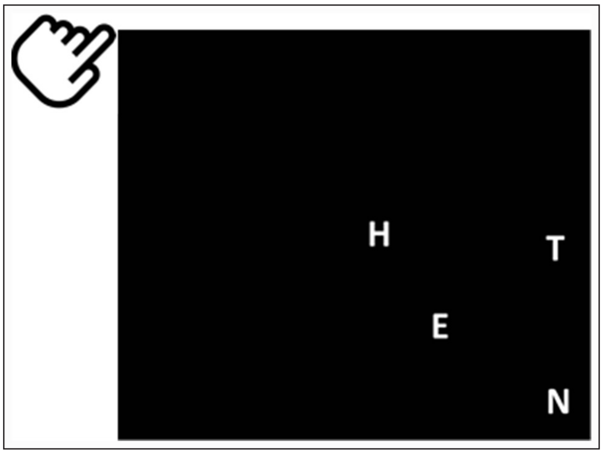

Figure 4: Example display of when the search array appears only in the relatively far region of space of the hand when placed at the upper-left corner of the screen for set size 4.

Thus, there were 500 experimental trials in total. They also completed another 20 practice trials before the start of the experimental trials.

Thus, set-size (4 & 7) and target distance ('near', 'far' or 'no-hand') were the independent variables, and reaction rime (RT; reported in milliseconds) to the target alphabets 'E' and 'F' and accuracy in identification were the dependent variables. After each block, there was a short enforced break lasting for 30s. Participants could choose to continue the experiment by pressing a key after the 30s.

2.3 Results

Pre-processing: Mean percentage errors and mean correct RTs were calculated separately for each participant and factor combination (see **Table 1**). Overall, the error rate was low (2.7%). The raw data was cleaned up to remove the trials with incorrect response (2.7% trials) and outliers in which the RTs that were ±2.5 SD from the mean RT (2.8% trials).

Analysis: In order to correct for any possible speed-accuracy trade-off, inverse-efficiency scores were calculated by dividing reaction time per participant per condition by proportion of accurate responses (See Townsend & Ashby, 1983; Sunny & von Muhlenen, 2013 for details). To determine whether hand presence affected attention, a 2 × 3 Bayesian repeated measures ANOVA (as described in Zoltan, 2014; Wagenmakers, 2007) was performed using the JASP software (Love et al., 2015) on the inverse efficiency scores, with set-size (4 & 7) and target distance (far, near & no-hand) as factors (See **Figure 5**). The Bayesian analysis was used since the approach can compare and evaluate the relative strength of evidence for the null and alternative hypotheses, and provide clear quantification of the degree to which the data support either hypothesis (as described in Masson, 2011; see also Wagenmakers et al., 2017).

Table 1: Mean Percentage of Errors and Standard Error (in parentheses) for the 'Far', 'Near' and the 'No-hand' conditions in Experiment 1.

Hand conditions	Set size 4	Set size 7
Far	3.1 (.65)	2.3 (.51)
Near	2.7 (.53)	1.9 (.48)
No-hand	3.3 (.91)	2.9 (1.1)

This analysis uses the Bayesian Information Criteria (P_{BIC} ($H_1|D$) to determine whether the alternate hypothesis, H_1, is true given the available set of data, D. The probability of the null hypothesis can be computed as $P_{\text{BIC}}(H_0|D) = 1 - P_{\text{BIC}}(H_1|D)$. The analysis also provided the Bayes Factor (BF), indicating the relative strength of the alternate hypothesis with respect to the null hypothesis. For e.g., $BF = 10$ means that the data favor the alternate hypothesis 10 times more than the null hypothesis. The Bayes factor (BF) varies from 0 to ∞, with BF much greater than 1 implying strong evidence for the alternate hypothesis, closer to 0 indicating strong evidence for the null hypothesis, and closer to 1 indicating that the data is insensitive to either of the hypotheses (Dienes et al., 2014).

The analysis was done on the factors target distance (near, far and no-hand) and set size (4 and 7), using a weakly informative prior, allowing us to compare the likelihood of a model (the null model with no factors included) with respect to another model. It was found that the analysis most favored the model containing the main effect of set size ($P_{\text{BIC}}(H_1|D) = .56$; $BF > 1000$). Overall, participants were

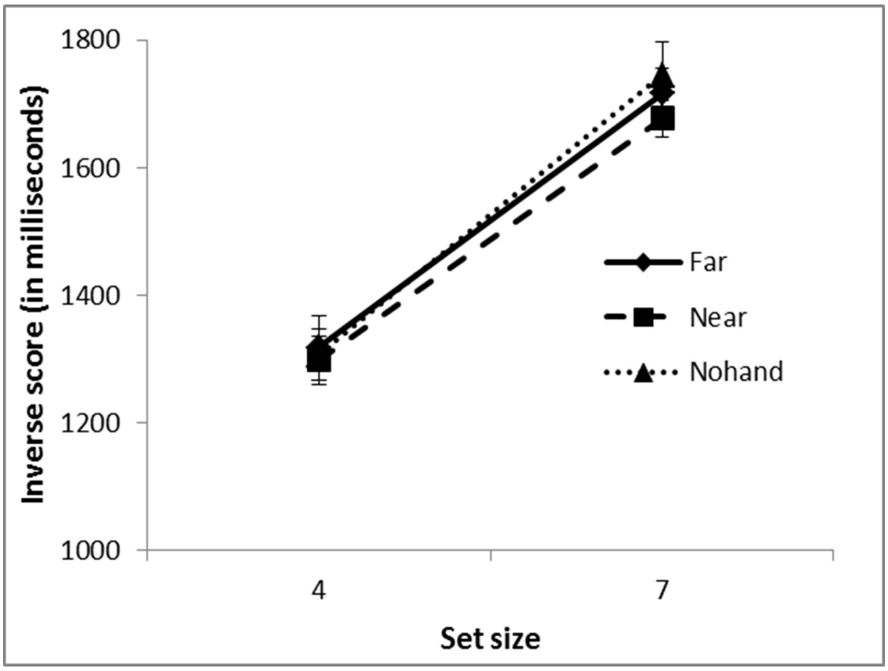

Figure 5: Inverse efficiency score of the 'Far', 'Near' and 'No-hand' conditions for set sizes 4 and 7. Error bars represent standard error of the mean.

faster at set size 4 (mean = 1274 ms, SE = 35 ms) compared to set size 7 (mean = 1674 ms, SE = 31 ms), indicating a strong set size effect. However, the analysis least preferred the model supporting the main effect of target distance ($P_{BIC}(H_1|D) < 10^{-37}$; *BF* = 0.11); the mean values of 'far', 'near' and 'no-hand' conditions being 1516 ms (SE = 35 ms), 1487 ms (SE = 29 ms), and 1525 ms (SE = 37 ms), respectively. Similarly, the analysis failed to support the evidence of an interaction between target distance and set size ($P_{BIC}(H_1|D)$ = .38; *BF* = 0.38). Taken together, the analysis strongly supported the null hypothesis- suggesting the absence of hand-proximity effects, but highlighting the sensitivity of the effect to the spatial arrangement of items in the search array. The same analysis on the median RT revealed similar results (set size: $P_{BIC}(H_1|D)$ = .89; *BF* = 32; target distance: $P_{BIC}(H_1|D) < 10^{-30}$; *BF* = 0.09; and interaction: $P_{BIC}(H_1|D)$ = .19; *BF* = 0.21).

2.4 Discussion

The present experiment investigated if restricting the visual search display to regions that are either near or far from the hands affected HPE. Participants completed a letter search task in two conditions; 'hand' condition- where their non-dominant hand was placed on each corner of the display as instructed, and the 'no-hand' condition- where the hand rested on the lap. In both conditions, the search array appeared only in part of the display. In the hand condition, this translated to either the region near or far away from the hand with the respective far and near regions being empty. The search rate given by the slope of the RT × Display size function showed that this manipulation did not change search efficiency for either near or far condition, as compared to the baseline condition. The findings imply that HPE might reflect the relative prioritization of objects closer to hand over objects far from the hand. However, when the search is restricted to only space that is either only near or only far, then there are no such effects.

Previous studies have reported slower attentional disengagement for objects in the proximal regions of the hand (Abrams et al., 2008; Thomas & Sunny, 2017). They argued that the presence of the hand near the search display made it harder to disengage from distractors in the display. The current finding does not replicate earlier findings of slower disengagement (Thomas & Sunny, 2017; Abrams et al., 2008).

Some studies have shown that it is possible to 're-size' the extent of the boundary of the near-hand space, effectively making both our 'near' and 'far' conditions as near-hand space. (Noel, Blanke, Magosso & Serino, 2018; Magosso, Ursino, di Pellegrino, Ladavas & Serino, 2010; Serino, Canzoneri, Marzolla, di Pellegrino & Magosso, 2015). This re-sizing would evoke the same underlying neural network in the processing of both 'near' and 'far' spaces of the hand (Noel et al., 2018). That is, as seen in the present study, we would observe similar search rates for both 'near' and 'far' conditions if the 'far' condition was re-sized. However, this explanation is unlikely as HPE would still be observed as a difference in search rates between the hand and no-hand conditions.

3 Experiment 2

3.1 Introduction

In the present experiment, we investigate the effect of distance from the hand on HPE even when both the 'near' and the 'far' space is populated with search relevant objects. However, unlike a typical visual search display where the items are randomly distributed, in the present experiment, we used a linear presentation. Specifically, the search array consisted of eight equally distanced items presented from the left to the right of the visual display with a jitter of ±1 cms added on the vertical plane so that the items in the search display do not line-up. This arrangement was expected to provide a clearer measurement of the effect of distance of the target from the hand on HPE.

Participants completed the task either with their hand placed at the sides of the display as instructed or placed on the lap. A near-hand effect would be evident in the form of RT differences for target as a function of its distance from the hand. Any HPE should be reflected as the difference between the hand and the no-hand conditions.

3.2 Method

3.2.1 Participants

18 students from IIT Gandhinagar were paid to participate in the experiment (11 males and 7 females; mean age-24.5 years). All the participants were right-handed and had normal or corrected-to-normal vision. All experimental, as well as data management protocols, were approved by the Technical Committee of the IITGN Institutional Ethics Committee (IEC). Experimental design and data collection was conducted in accordance with the guidelines and regulations of the IEC. Informed consent was obtained from all participants before the study began.

3.2.2 Apparatus and Stimuli

The apparatus and the stimuli used were the same as in experiment 1. The stimulus consisted of fixation cross and letters. The letters consisted of 'E' or 'F', along with 'H', 'L', 'M', 'N', 'P', 'Z' and 'U'.

3.2.3 Design and Procedure

The design and procedure were similar as in experiment 1, except that in the 'hand' condition, participants had the index finger of their non-dominant hand rested at the centre of the left or the right sides of the computer monitor, when instructed. In the 'no-hand' condition, the non-dominant hand rested on the lap. A search array consisting of 8 letters appeared followed by a fixation cross, with participants were asked to look for a target letter 'E' or 'F' among other letters and respond as fast as they can while keeping the errors to a minimum. The target was equally likely to appear in any of the eight target locations separated by a horizontal distance of 5 cm from each other, arranged in the centre of the display (see **Figure 6**).

The location of each search item had a random vertical spatial noise ranging upto 1 cm, ensuring that the search array never appeared in a straight horizontal line. The participants completed the hand condition, where they rested their non-dominant hand in such a way that the index finger rested on each side of the monitor in a pointing gesture (see **Figure 6**).

At each of the 8 locations, participants completed 88 trials, equally divided between the hand-on-the-left and hand-on-the-right side of the display. In the 'no-hand' condition they completed 176 trials of the same visual search task. The order in which the participants completed the 'hand' and 'no-hand' conditions were also counterbalanced across participants. Thus, there were 352 experimental trials in total. They also completed another 20 practice trials before the start of the experimental trials. Thus, hand position ('left', 'right' or 'no-hand') and target locations (positions: 1, 2, 3, 4, 5, 6, 7, and 8) were the independent variables, and reaction time (RT; in milliseconds) to the target alphabets 'E' and 'F' and accuracy of identification were the dependent variables. HPE would be evidenced by a significant interaction between the two factors.

3.3 Results

Pre-processing: Mean percentage errors were calculated separately for each participant and factor combination (see **Table 2**). Three participants were removed from the analysis because of their overall high error rate (>5%).

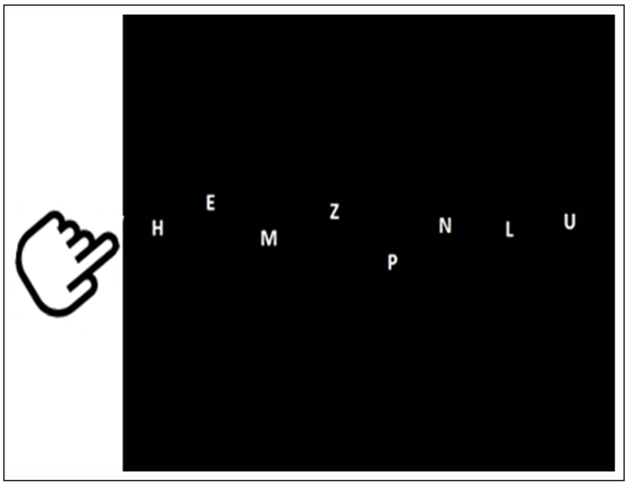

Figure 6: Example display of the 'Hand-left' condition, where participants rested their hand on the left side of the monitor in such a way that the index finger rested on the left side in a pointing gesture. The search array appeared horizontally. In the example display, the location of the target ('E'), being one among the four locations on the same side as the hand position, makes it relatively near compared to the target locations on the other (right) side of the display.

The raw data was cleaned up to remove the trials with incorrect response (3.1% trials) and outliers in which the RTs were ±2.5 SD away from the mean RT (2.9% trials). For each participant, the mean correct response times was calculated for targets appearing at eight locations (from left to right) for each of the hand conditions (positioned on the left & right sides of the display and the lap; see **Figure 7**).

Analysis: In order to rule-out any possibility of a speed-accuracy trade-off, the RTs were adjusted by calculating the inverse-efficiency scores.

To determine whether there is any spatial gradation pattern in the allocation of attentional resources, a Bayesian repeated measures ANOVA was performed on the RT, with target location (1, 2, 3, 4, 5, 6, 7 and 8) and hand-position (left, right & no-hand) as factors. The analysis most favoured the model containing the main effect of the target location, (P_{BIC} ($H_1|D$) = .35; *BF* > 1000). Overall, the RT was found to increase from target locations nearer to the fovea towards the left (target locations 4 (mean = 932 ms, SE = 44 ms), 3 (mean = 1014 ms, SE = 51 ms), 2 (mean = 1148 ms, SE = 55 ms) and 1 (mean = 1375 ms, SE = 58 ms) and right sides of the display (target locations 5 (mean = 951 ms, SE = 51 ms), 6 (mean = 1104 ms, SE = 49 ms), 7 (mean = 1293 ms, SE = 53 ms) and 8 (mean = 1527 ms, SE = 51 ms); reflecting a centre/periphery bias in performance. However, the analysis failed to find evidence supporting the main effect of hand-position, (P_{BIC} ($H_1|D$) < 10^{-72}; *BF* = .15); mean RT of 'hand-right', 'hand-left' and the baseline 'no-hand' conditions were, 1198 ms (SE = 54 ms), 1170 ms (SE = 53 ms) and 1137 ms (SE = 47 ms), respectively. Critically, the analysis least preferred the model containing the interaction between target location and hand position, (P_{BIC} ($H_1|D$) =.004; *BF* = 0.06); suggesting the absence of hand-proximity effect. Same analysis on the median RT also revealed similar results; Target Location: P_{BIC} ($H_1|D$) = .004; *BF* = 0.06, Hand Position: P_{BIC} ($H_1|D$) < 10^{-67}; *BF* = 0.21, and interaction: P_{BIC} ($H_1|D$) = 0.006; *BF* = 0.007.

3.4 Discussion

The present experiment investigates the effect of distance from the hand on HPE when both the near and the far space is populated with search relevant objects. The objects in the search display were arranged in a line on the horizontal plane. The target appeared in one of the eight locations, making the search relatively more structured as compared to a typical letter search task. Participants responded to the target with their dominant hand, while

Table 2: Mean Percentage of Errors and Standard Error (given in parentheses) for each of the hand positions for all the eight target locations in Experiment 2.

Hand position	1	2	3	4	5	6	7	8
Hand-left	4.8 (1.7)	1.7 (1.1)	3 (1.3)	1.3 (.74)	2.1 (1.1)	2.6 (1.0)	2.7 (.97)	5.4 (1.2)
Hand-right	3.6 (1.2)	5.2 (1.6)	3.8 (1.5)	2.7 (.96)	2.3 (.94)	2.3 (1.3)	3.1 (1.1)	2.6 (1.1)
No-hand	3.5 (1.1)	2.6 (.67)	1.7 (.67)	2.6 (.92)	2.1 (.81)	2.6 (.97)	2.6 (.88)	5.2 (1.3)

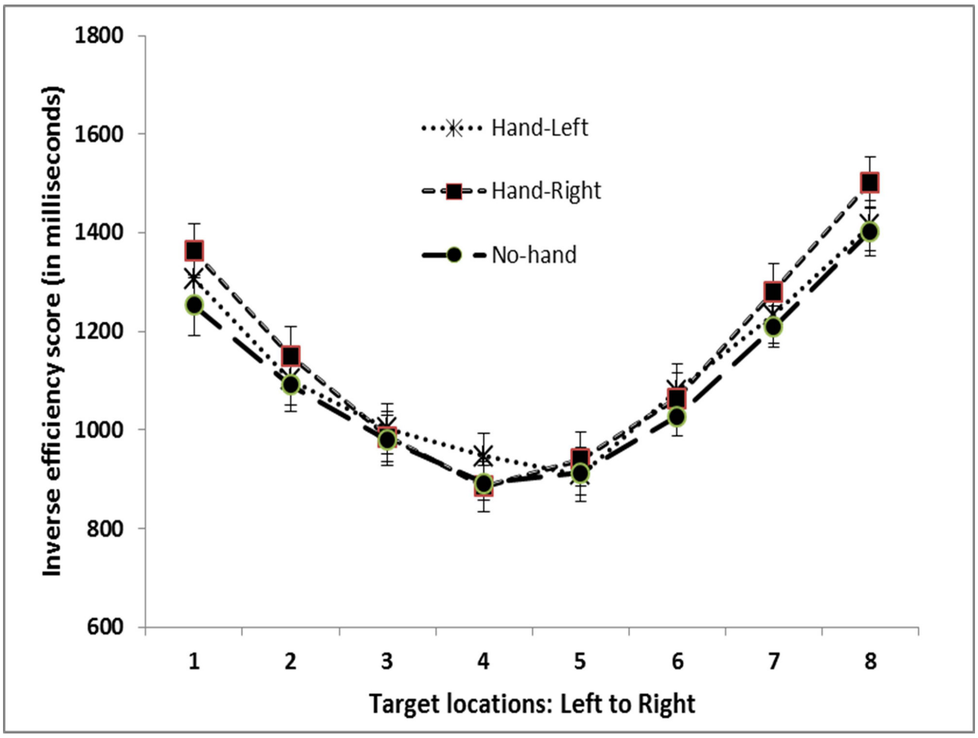

Figure 7: Inverse efficiency score for hand positioned on the left ('Hand-Left'), right ('Hand-Right') and baseline ('No-hand') conditions. Error bars represent standard error of the mean.

their non-dominant hand rested either on the left or the right side of the display as instructed or on the lap (baseline 'No-hand' condition). The results showed an absence of HPE. That is, RT differences were not observed for either hand positions in any of the 8 target locations compared to the baseline no-hand condition.

The present results suggest that the mere presence of objects in near as well as far locations simultaneously- as compared with the partial display in experiment 1- is not sufficient for the appearance of HPE. The increased predictability of target location seems to have overridden any hand-specific processing advantages for targets appearing near the hand position.

It is possible that the current experimental design failed to capture changes in the attentional mechanisms in the near region of space compared to the far, because of the absence of set size manipulation. That is, if the HPE is task-dependent, not having set size manipulation may not have tapped into any attentional processing differences between the hand-present and the hand-absent (baseline) conditions. It seems the HPE gets manifested in a specific conducive environment only; requiring future studies to have an experimental design that can fully capture the nuanced nature of the HPE.

Nevertheless, the overall RT was found to be significantly smaller for targets appearing closer to the center of the display as compared to the periphery. This is evident in the significant main effect found for target location. Various studies have shown similar results where they found participants to be both faster and more accurate when presented with stimuli at the foveal region as compared with the visual periphery (Carrasco et al., 1995; Wolfe, 1998; Staugaard, Peterson & Vankgilde, 2016). Also, such an advantage for target locations near the central fixation cross seems to override any hand-specific RT facilitation for targets appearing nearer to the hand when positioned on either side of the display.

Also, the current results show a trend of relatively faster RT (though not statistically significant) for targets appearing in the left side of the display as compared to the right. This has been observed previously in the literature and has often been attributed to the direction of the writing system (Pierson-Savage & Bradshaw, 1987; Maass & Russo, 2003; Chan & Bergen, 2005). The present experiment had participants who would most likely have a left-to-right *first-preferred-side-to-focus-upon* preference-since they were Hindi- and English-speakers-and nothing hand-specific.

4 General Discussion

The present manuscript reports two experiments that used a visual search task to look at the potential effect of hand position on visual processing. Experiment 1 had the search array presented either only in the near or far region of space of the hand, whereas experiment 2 had the horizontal axis of items in the search array kept fixed, making the targets appear at relatively predictable locations. Both studies failed to find evidence for hand-proximity effect (HPE). For instance, studies have failed to find the predicted near-hand-related processing effects on visual memory, visual search, and change detection (Andringa, Boot, Roque, & Ponnaluri, 2018; Sahar & Makovski, 2017). Another set of studies has only been able to show partial HPE (Le Bigot & Grosjean, 2016; Langerak, La Mantia & Brown, 2013; Lloyd, Azanon & Poliakoff, 2010). For example, Le Bigot & Grosjean (2016) found cueing effect to be larger near the right hand compared to the left hand for both peripherally (and uninformatively) cued and centrally (and informatively) cued stimuli presented at peripheral locations. Lloyd et al., (2010) also found similar results using a covert visual orienting task, where participants were required to discriminate between a yellow-filled triangle and a yellow-filled circle presented at a location that was uninformatively cued. The cueing effects were found to be significantly greater near the right hand, with no such effects found near the left hand.

Previous studies have shown the extent of the peripersonal space (PPS) boundary to be dynamic-expanding and contracting, based on the interactions made with the environment such as tool-use (Iriki et al., 1996; Berti & Frassinetti, 2000), or dependent on nature of stimuli such as velocity of an approaching stimulus (Noel, Blanke, Magosso, & Serino, 2018). However, as suggested earlier, this might not be a good explanation of our findings of no HPE as we measured the basic effect of hand proximity as the difference between the hand and no-hand conditions.

Another possible explanation for not finding HPE could be that the distance that was considered as ‘far’ in experiment 1 was not far-enough to have resulted in the re-allocation of resources between the magnocellular and parvocellular pathways to bias processing of items presented in the near and far region of spaces, respectively. Similarly, the nature of the task was such that it did not allow for the re-allocation of resources between the magnocellular and parvocellular pathways. That is, a letter identification search task is more feature-based and perhaps biases the processing towards the ventral processing stream, not complementing the more action-based dorsal processing for stimuli presented near the hand. Therefore, it is not surprising to find comparable search rates for items in the near and far region of spaces of the hand with the baseline no-hand condition. Maybe a task that made use of features like motion or color would be more sensitive to HPE.

Also, in the present experimental design, the hand positioned on the left and right side of the display, along with the no-hand condition together constitute three hand positions. Perhaps this explains the inability to find evidence for HPE, in line with the findings of Schultheis and Carlson (2013), where employing more than two hand positions in the same experiment was found to eliminate the HPE.

However, the present findings are in contrast with that of Thomas & Sunny (2017), where using a standard visual search task, evidence for disengagement effect was obtained for targets appearing in the ‘near’ region of the hand, compared to the targets appearing relatively ‘far’ and the baseline ‘no-hand’ conditions. Abrams et al., (2008) also found similar results with a standard letter search task. Hence, it is possible that the spatial extent and arrangement associated with such tasks is important to observe HPE.

Recently, Dosso and Kingstone (2018) argued that hand proximity effects are fragile. Our results seem to agree with these conclusions at least partially. On the other hand, the current results could also point to the extremely specific nature of the hand proximity effects. While researchers have struggled to explain the nature and mechanisms underlying HPE using behavioral manipulations, there is a set of robust neuroscientific work on HPE. For instance, the near and far regions of space of the body seem to get processed in different regions in the brain (Berti & Frassinetti, 2000, 2002; Cowey, Small, & Ellis, 1994, 1999; Halligan & Marshall, 1991; Vuilleumier, Valenza, Mayer, Reverdin & Landis, 1998). Evidence for such modularity comes from lesion studies. For example, Rizzolatti et al., (1983) found that ablation of the postarcuate cortex (area 6) in macaque monkey lead to severe contralateral visual and somatosensory neglect that is only limited to the near-space. Whereas ablation of area 8 (frontal eye fields) lead to deficits in the visual processing of objects falling in the contralateral space, with the deficit more pronounced only in the far-space and not accompanied by somatosensory deficits (Latto & Cowey, 1971). Similarly, many other studies also give evidence for differential involvement of the brain in the coding of the far and the near space, respectively. Colby, Duhamel, and Goldberg (1996) showed that neurons in area LIP might be another neural substrate for the representation of far space in monkeys. On the contrary, near-space seems to be represented in frontal area 6 and in the rostral part of the inferior parietal lobe, e.g., in area 7b (Leinonen, Hyvarinen, Nymani, & Linnankoski, 1979) and in area VIP (Duhamel, Bremmer, Ben Hamed, & Graf, 1997; Colby, Duhamel, & Goldberg, 1993). Similarly, in two studies Weiss and colleagues (Weiss, Marshall, Wunderlich, Tellman, & Halligan, 2000; Weiss, Marshall, Zilles & Fink, 2003) found activations in the parietal and premotor cortex for tasks performed in near space, and ventral occipital and medial temporal cortex for tasks performed in far space. However, these may not translate to visual processing differences at a behavioral level; situational determinants such as the number of hand postures (Schultheis & Carlson, 2013) and top-down factors (Garza et al., 2013) seem to play a crucial role in observing HPE.

Therefore, the HPE seems to be sensitive to the task demands, perhaps requiring a much careful thought in designing the task used for testing it. This seems true, especially considering that the HPE is subtle and nuanced (Gozli et al., 2012; Kelly & Brockmole, 2014; Bush & Vecera, 2015). The current findings also suggest that any hand-mediated changes result in bias at the attentional level depending on situational factors that are conducive enough for the effect to get manifested.

Data Accessibility Statement

All the participant data and the MATLAB script used for running the experiments reported in this manuscript are available at (https://repository.iitgn.ac.in/handle/123456789/3922).

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Competing Interests

The authors have no competing interests to declare.

Author Contributions

- Conception and design: TT, MS
- Data acquisition: TT
- Analysis and interpretation of data: TT, MS
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