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RESEARCH ARTICLE

Reduced object-based perception in the near-hand space

Jihyun Suh[1] · Richard A. Abrams[1]

Abstract Previous studies have shown that hand proximity changes visual perception (Abrams et al. in Cognition 107(3):1035–1047, 2008). The present study examined the effects of hand proximity on object-based perception. In three experiments, participants viewed stimuli that were either near to or far from their hands. The target stimulus appeared, after a cue, in one of two rectangular objects: either at the location that had been previously cued, at the uncued end of the cued object, or in the uncued object. We found a significantly reduced same-object benefit in reaction time for stimuli near the hands in one experiment. Interestingly, we observed a same-object cost in sensitivity for stimuli near the hands in another experiment. The results reveal that object-based perception is disrupted in the near-hand space. This is consistent with previous findings revealing altered visual processing near the hands.

Keywords Embodied cognition · Visual attention · Near-hand vision · Object-based perception

Introduction

Connections between perception and action have received careful scrutiny since the time of Woodworth (1899). Recently, such connections have received increasing attention in part because it has become clear that not only does vision influence action, but action can also influence visual perception (for a review, see Abrams et al. 2015). Given the

fact that the hands are major effectors for action in everyday life, many researchers are investigating the relationship between vision and the hand.

Growing evidence has shown that the proximity between the hand and visual stimuli can alter visual experience. Numerous changes in perception have been observed when the hands are located close to the visual stimuli. For example, Abrams et al. (2008) found that hand proximity influences aspects of visual attention. In one of their experiments, participants performed a visual search task while both of their hands were held either on the sides of the monitor (and hence, the visual stimuli were in the near-hand space) or on their lap (when the visual stimuli would be far from the hands). Participants searched through the stimuli at a slower rate when the hands were near the visual display. Additional evidence has suggested that hand proximity affects numerous aspects of visual processing including perception, attention, and cognitive control (see Brockmole et al. 2013, for a review).

One explanation for the changes in vision near the hands is that visual processing in the near-hand space is believed to be biased in favor of subsequent action plans (Bekkering and Neggers 2002; Gozli et al. 2012; Thomas 2013). That is because, typically, events happen in the near-hand space that would require direct interactions with the hand—such as by touching, grasping, or holding. Therefore, placing the hand nearby visual stimuli could increase a readiness to perform an action. For instance, Brown et al. (2008) have shown that placing one hand near a visual object improved the ability to estimate the size of the object in the blind visual field of brain-damaged patients. This suggests that size perception might be enhanced in the near-hand space to facilitate successful grasping actions.

Other changes in vision near the hands may also facilitate action. When the readiness for action increases,

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cognitive capacity can be expanded to prevent potential errors because it could be hazardous when an action is mistakenly performed (e.g., grasping a hot iron). Therefore, visual processing in the near-hand space would require enhanced interpretation of an attended stimulus. In support of this account, several studies have reported enhanced cognitive control near the hands evidenced by reduced Stroop interference (Davoli et al. 2010), reduced task-switching costs (Weidler and Abrams 2014), augmented attention to detail (Davoli et al. 2012), and increased visual working memory capacity (Tseng and Bridgeman 2011).

Additionally, some studies have suggested that visual information in the near- and far-hand space might be projected to the brain in different ways (Abrams and Weidler 2014; Goodhew et al. 2013; Goodhew et al. 2014; Gozli et al. 2012, 2014). This work suggests that the magnocellular pathway, one of the two major visual processing channels, could be more heavily involved in processing visual inputs in the near-hand space. The magnocellular pathway is known for its preference to motion and luminance change, and it has high temporal but low spatial resolution, which is specifically relevant to action (Goodale 2008; Goodale and Milner 1992; Goodale and Westwood 2004). For example, Abrams and Weidler (2014) found that participants were more sensitive to low-spatial-frequency (LSF) stimuli and less sensitive to high-spatial-frequency (HSF) stimuli when the hands were near to the stimuli. This selective bias toward LSF information in the near-hand space disappeared when the magnocellular pathway was suppressed by illumination in the display with diffuse red light. Consistent with this finding, Goodhew et al. (2013) have observed reduced object substitution masking (OSM) in the near-hand space. That occurs when an observer fails to segregate two sequentially presented objects. Goodhew et al. (2013) suggested that the smaller OSM in the near-hand space was caused by enhanced processing on the magnocellular pathway leading to increased temporal resolution that enabled individualization of the stimulus objects. The overall findings indicate that enhanced processing on the magnocellular pathway may underlie much of the altered visual experience in the near-hand space.

So far, little is known about whether hand proximity also affects object-based visual processing, the focus of the present study. Egly et al. (1994) introduced the idea that attention may spread within the boundaries of objects in accordance with gestalt grouping principles (e.g., Duncan 1984). In their experiment, two rectangles were presented followed by a cue at one end of one of the rectangles. Participants were asked to detect a target which appeared later at one of three possible locations: (a) at the cued location, (b) at the uncued end of the cued rectangle, or (c) at an uncued location on the other rectangle. Not surprisingly, participants' responses were fastest when the target

appeared at the cued location. Critically, reaction time (RT) was also faster when the target appeared at the uncued end of the rectangle that was previously cued compared to in the uncued rectangle, even though targets in those two conditions were equally distant from the cued location. This *same-object benefit* indicates that not only a target appearing in the cued location, but also one elsewhere on the cued object receives attentional priority.

A recent report of Gozli et al. (2014) examined feature binding and is relevant to object-based processing near the hands. In their experiment, two letter symbols were presented inside of two horizontally located placeholders and participants were asked to remember the letters. Then, the placeholders moved 90° until they were vertically aligned, followed by a target in one of the two placeholders. When one of the to-be-remembered symbols was presented as a target in its original placeholder, compared to when it was in the alternative placeholder, participants were faster to identify the target symbol—the so-called *object-preview effect* (Kahneman et al. 1992). The underlying idea of the object-preview effect is that attention integrates different features (e.g., color, shape, and location) into a unified episodic representation (an *object-file*). When the same features are repeated in a new location, RT should be faster compared to when the features change because updating an existing object-file is easier than creating a new one. Gozli et al. (2014) found a considerable object-preview effect when the hands were far from the visual stimuli but no object-preview effect when the hands were nearby the visual stimuli. Whatever the explanation, if object-based processing relies on the same mechanisms that support feature binding in the object-preview effect, then these results suggest that object processing may be reduced in the near-hand space.

Gozli et al. (2014) attributed their findings to enhanced processing along the magnocellular pathway and reduced processing on the parvocellular pathway in the near-hand space. As discussed earlier, there is considerable support for such processing changes near the hand (e.g., Abrams and Weidler 2014; Gozli et al. 2012). Gozli et al.'s (2014) conclusion fits well with those of Davis (2001; Davis and Holmes 2005). Those researchers presented targets and rectangular objects simultaneously, which prevents processing of the objects in advance. Davis et al. proposed that simultaneous presentation would favor the fast processing of the magnocellular channel over the slower processing of the parvocellular channel. The result of such processing, according to Davis (2001; Davis and Holmes 2005) would be a strengthening of binding of features between objects, and a relative weakening of within-object binding. Indeed, Davis found such a pattern: under simultaneous presentation of targets and rectangles, participants revealed a same-object cost, not a same-object benefit. Other experiments

by Davis supported the claim that the observed object processing changes were caused by differential processing on the magnocellular and parvocellular pathways. Similarly, Humphreys (1998) proposed that between-object binding would rely more heavily on the dorsal processing stream, which is heavily innervated by the magnocellular pathway. Thus, enhanced magnocellular processing would strengthen between-object connections (at the expense of, or relative to, within-object connections). Given those findings, if indeed magnocellular processing is enhanced near the hands, object-based attention might be expected to be reduced or even reversed in the near-hand space.

Even though altered visual processing in the near-hand space has been found in many studies, what makes visual processing near the hands unique has still not been fully answered. Since humans use the hands as tools for action, much of our everyday experience in near-hand space necessitates hand movements. Due to the tight connection between visual and motor systems, visual processing in near-hand space may be biased to potential action plans. In particular, attention could be automatically tuned to action-relevant information (e.g., location) rather than feature-relevant information (e.g., color). For example, Tipper et al. (1992) have suggested that actions could influence perception by causing people to adopt an action-centered framework. Similarly, people might adopt an action-centered framework when the hands are placed nearby the visual stimuli. When people adopt an action-centered framework, they might become more sensitive to space-based 'where' information but less sensitive to feature-based 'what' information such as the shape of visual objects. Such a change might be expected to reduce the importance of the objects, resulting in a reduced same-object benefit near the hands.

While no study has yet examined effects of hand proximity on object-based processing, several studies have examined the influence of different types of hand movements. For example, Linnell et al. (2005) found that object-based processing was disrupted (i.e., the same-object benefit was reduced) when the task required a pointing movement as a response. They concluded that, when action is made to an object, space-based attention overrides object-based attention. Linnell et al. interpreted the result as showing that the attentional system is flexible, so that a programmed movement can change the extent of the relative influence of space- or object-based attention.

Fischer and Hoellen (2004) conducted a conceptually similar experiment. They also examined the extent to which the nature of a planned movement could affect object-based processing. They found no same-object benefit when participants were required to make a pointing response—similar to Linnell et al.'s reduced same-object effect under similar conditions. However, Fischer and Hoellen found an enhanced same-object benefit when a grasping movement

was required as the response. Thus, it seems that preparing a movement may enhance or reduce the object-based effect, depending on the nature of the movement.

Based on the preceding findings, it is clear that object-based processing may depend on whether and what type of hand movement a person intends to direct toward a target. However, it is not known whether merely placing the hands near a visual stimulus without a specific movement plan would also produce changes in object-based visual processing. Answering that question was the purpose of the present study. Egly et al.'s (1994) two-rectangle paradigm was used to measure the same-object benefit near to and far from the hands. Participants were asked to identify a target that appeared at the cued location, in the uncued end of the cued object, or on the uncued object while their hands were placed either near to or far from the display. In Experiment 1, participants performed a letter-discrimination task. In Experiments 2A and 2B, participants were asked to identify the orientation of a briefly presented sine-wave grating (Gabor patch). In each experiment, the same-object benefit was compared between near- and far-hand space.

If visual objects in the near-hand space are viewed as candidates for potential grasping actions, that may cause preferential processing of the objects (e.g., rectangles) resulting in a stronger same-object benefit in the near-hand space, consistent with the findings of Fischer and Hoellen (2004). However, if placing the hands near visual stimuli potentiates space-based attention but disrupts object-based attention, as has been reported for pointing hand movements (Linnell et al. 2005), then there will be a reduced or eliminated same-object benefit. Either outcome would aid in a better understanding of the changes in processing that occur near the hands.

Experiment 1

The purpose of Experiment 1 was to examine whether hand position affects object-based allocation of spatial attention. Egly et al.'s (1994) two-rectangle paradigm was used to measure the extent of the same-object benefit. Participants were asked to report a target letter that appeared at one of three locations imposed on two objects. Importantly, hand proximity was manipulated either near to or far from the visual display.

Method

Participants

Thirty Washington University undergraduate students participated to fulfill course credits. All of them had normal or corrected-to-normal vision.
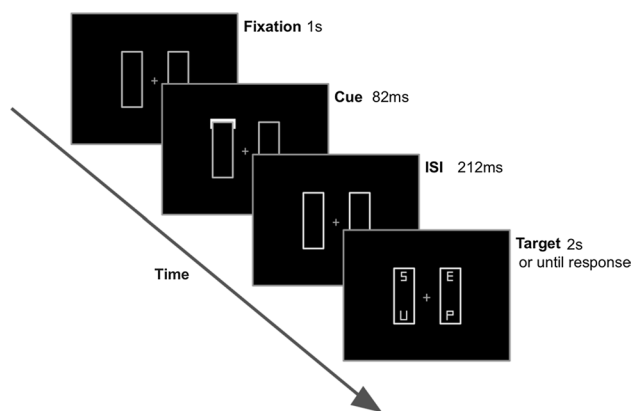
Fig. 1 Sample sequence of a trial in Experiment 1. The *two rectangles* were presented either horizontally or vertically. *ISI* inter-stimulus interval

Apparatus and procedure

Stimuli were presented on a 17-inch CRT monitor (resolution: 1280 × 1028, refresh rate: 85.5 Hz) in a dimly lit room. All experiments were programmed in Python using Psychopy (Peirce 2007). Hand position was manipulated either near to or far from the display. Two 5-cm-diameter round buttons were used to collect responses. In the near-hand position, one button was attached on each side of the monitor, with participants' elbows resting on foam cushions. In the far-hand position, the buttons were attached to a wooden board and placed on the lap of the participants. During the experiment, the participant's head was stabilized by a chin-rest to maintain a viewing distance of 45 cm.

Figure 1 shows the sequence of events on a trial in Experiment 1. All stimuli were presented in gray on a black background. A fixation point ('+', 1° × 1°) was presented at the center of the screen for 1 s. Two rectangles (3.3° × 10°, line width: .15°) were presented either horizontally or vertically 3.35° from fixation (center-to-center) for 1 s. One end of one rectangle was briefly brightened, serving as the cue (3.4° × 3.4°, line width: .2°) for 82 ms. After a 212-ms inter-stimulus interval (ISI), four letters (.8° × 1°) including one target letter appeared—one in each end of each rectangle. Participants were asked to search for and identify the target letter, either an S or an H, and respond by pressing the correct response button as quickly and accurately as possible. The target and distracter letters remained on the screen until a response was made, with a maximum duration of 2 s. A feedback message was given for incorrect or missed responses with an auditory tone (440 Hz) for 500 ms. The inter-trial interval (ITI) was 529 ms.

Design

Participants completed 16 practice trials followed by the main experiment, which consisted of two blocks of 128 trials each. Each target letter (S or H) was presented on half of the trials, in a random order, in each block. The target appeared at one of three possible locations: the cued location (50 % of the trials), the uncued-same-object location (the uncued end of the cued rectangle; 25 %), or the uncued-different-object location (the end of the uncued rectangle that was diagonally opposite the uncued-same-object location; 25 %). The two uncued locations were equally distant from the cued location. Each trial included one target (S or H) and three nontarget letters (one each of E, U, and P). The rectangles were oriented vertically on half of the trials and horizontally on the other half of the trials, and each orientation was randomly selected trial by trial. For each orientation, the target letter was equally likely to be presented at each end of each of the rectangles. Target–response mappings and initial hand position were counterbalanced across the participants. Half of the participants completed the first block with the near-hand position and the second block with the far-hand position. The other half of the participants completed the task in the opposite order. Each block had three self-terminated breaks.

Results

RTs above or below two standard deviations from the mean of each condition for each participant were removed from the RT analysis (3.52 % of total trials).

Reaction time

Mean RTs as a function of the hand position and target location are shown in Fig. 2. To examine the same-object benefit, a repeated measures ANOVA was conducted using only the uncued target locations with the factors of hand position (near or far) and target location (uncued-same-object and uncued-different-object). This revealed a significant main effect of target location, $F(1, 29) = 11.473$, $p = .002$, $\eta_p^2 = .283$. RT was faster for targets on the same object compared to the different object revealing a significant same-object benefit. Importantly, we also found an interaction between hand position and target location, $F(1, 29) = 5.929$, $p = .021$, $\eta_p^2 = .170$. The same-object benefit was smaller with the near-hand position ($M = 6.5$ ms) than the far-hand position ($M = 31.04$ ms).

Post hoc pairwise comparisons revealed that the same-object benefit was significant in the far-hand
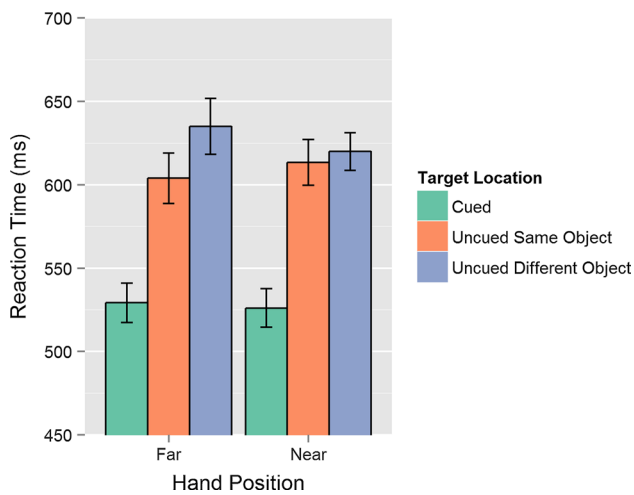
Fig. 2 Mean reaction time as a function of hand position and target location in Experiment 1. *Error bars* represent within-subject standard errors

Table 1 Percentage of errors in Experiment 1

Hand position	Target location			
	Cued	Uncued-same-object	Uncued-different-object	Same-object benefit
Far	3.28	6.98	7.40	.42
Near	2.71	7.40	7.92	.52
Mean	2.99	7.19	7.66	.47

space, $t(29) = 4.114$, $p < .001$, $d = .354$, but not in the near-hand space, $t(29) = .874$, $p = .390$, $d = .094$, indicating elimination of the same-object benefit in the near-hand space.

In addition, the magnitude of the spatial cueing effect was examined by analyzing the RT for target locations on the cued object (cued- and uncued-same-object conditions). A repeated measures ANOVA revealed a main effect of target location, $F (1, 29) = 73.676$, $p < .001$, $\eta_p^2 = .718$, with RT faster for the cued location compared to the uncued-same-object location. The main effect of hand position, $F (1, 29) < 1$, and the interaction, $F (1, 29) = 1.859$, $p = .183$, $\eta_p^2 = .060$ were not significant.

Percentage of error

Table 1 shows the percentage of error in each condition.

A hand position × target location repeated measures ANOVA including only the uncued locations showed that none of the main effects or interaction were significant. A repeated measures ANOVA including only the target locations on the cued object did not reveal any significant main effects or interaction, $Fs (1, 29) < 1$.

Discussion

A considerable same-object benefit was observed when the hands were far from the visual stimuli, as originally reported by Egly et al. (1994). However, this benefit disappeared when the hands were located nearby the stimuli. A reduced same-object benefit in the near-hand space is surprising but not a totally unexpected result. Indeed, it is consistent with previous findings of disrupted object-based processing with planned hand-pointing movements (Linnell et al. 2005). The present result, however, showed an impaired object-based visual processing even though participants were not planning actual movements. One possible explanation is that positioning the hands nearby visual stimuli might have automatically activated a potential hand movement (cf. Abrams et al. 2015), resulting in an attentional bias to the space (e.g., target location) instead of objects (e.g., rectangles). This seems feasible, given that accurate hand movements might depend most on 'where' the object is instead of 'what' the object is.
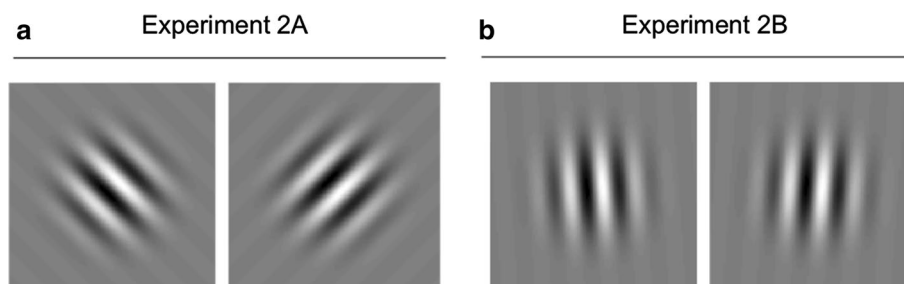
The results are also in agreement with Gozli et al. (2014), who found impaired feature binding near the hand. According to their account, the reduced same-object benefit observed in Experiment 1 also could be due to participants failing to bind the letters and rectangles together as a unified object in the near-hand space. The feature binding is thought to occur relatively late in visual processing, once all the visual inputs are processed (Bouvier and Treisman 2010). However, it is also known that object-based visual processing occurs at an early visual processing stage. Muller and Kleinschmidt (2003) showed that the same-object benefit was observed in early visual processing (area V1). This implies that object perception might have been disrupted nearby the hand early in visual processing. In Experiment 2, we examined this possibility.

Experiment 2

The aim of Experiment 2 was to test whether hand proximity would influence object perception early in visual processing. Here, we measured perceptual sensitivity for the orientation of a briefly presented sine-wave Gabor patch. It is known that orientation sensitivity is mediated by orientation-sensitive cells in early visual cortex (Liu et al. 2007). Therefore, comparing sensitivity to the orientation of Gabor patches in a cued or an uncued object should reveal whether hand proximity influences object perception in early visual processing.

In Experiment 2A, a Gabor patch was presented that was tilted 45° either to the left or right. Because that discrimination was relatively easy, in Experiment 2B the Gabor patch was tilted only 4°, which made the task more challenging.

Fig. 3 Examples of Gabor patches (3.1 cycles/°) used in Experiment 2. Participants were asked to discriminate the orientation of the patch. **a** Gabor patch was tilted either 45° or −45° in Experiment 2A. **b** Gabor patch was tilted either 4° or −4° in Experiment 2B

a Experiment 2A

b Experiment 2B

Method

Participants

Thirty undergraduate students participated to fulfill course credits for Experiment 2A. Another thirty undergraduate students were recruited from the same pool for Experiment 2B. All of them had normal or corrected-to-normal vision.

Apparatus and procedure

All of the stimuli and procedures were identical to Experiment 1 except the target stimuli. Figure 3 presents examples of target stimuli used in Experiments 2A and 2B. A single Gabor patch (3.1 cycle/°, 2° × 2°)[1] was presented with 30 % of full opacity for one frame (≈12 ms). Participants were asked to press either the left or right button depending on the orientation of the Gabor patch as quickly and accurately as possible.

Design

Participants completed 12 practice trials followed by the main experiment, which consisted of two blocks of 160 trials each. A target was presented at either the cued location (40 %), the uncued-same-object location (20 %), or the uncued-different-object location (20 %). The uncued locations were equally distant from the cued location. In some trials (20 %), a target was not presented and participants were instructed to refrain from responding. Half of the participants completed the first block with the near-hand position and the second block with the far-hand position. The other half of the participants completed the task in the opposite order. Each block had four self-terminated breaks.

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[1] Abrams and Weidler (2014) showed that participants were more sensitive to identify low-frequency Gabor patches (2.1 cycle/°) than high-frequency Gabor patches (4.2 cycle/°) in the near-hand space. We used here a spatial frequency (3.1 cycle/°) in between those values.

Results

Due to a software error, the target on some trials was presented for two frames (≈24 ms, 1 % of total trials) instead of the intended one frame. A separate analysis was conducted without those trials, and their exclusion did not influence the results. Therefore, those trials were included in the analysis. We used A prime (Zhang and Mueller 2005) as a measure of perceptual sensitivity because some participants had perfect scores that made it implausible to use d prime.

Experiment 2A

Four participants whose error rate in any condition was above two standard deviations from the mean error rate (>22.98 %) were excluded from further analysis. The average error rate of those four participants was 19.73 % (SD = 9.47) and that of the remaining participants was 5.84 % (SD = 4.12). For the remaining data, RTs above or below two standard deviations from the mean of each participant were removed from RT analysis (4.45 % of total trials).

A prime

The Gabor patch tilted left was considered as a signal. The hit rate was the proportion of trials on which participants responded that the Gabor patch was tilted left participants made the same responses (i.e., left) for the Gabor patch tilted right. Figure 4a shows perceptual sensitivity as a function of hand position and target location. A repeated measures ANOVA using only the uncued target locations was conducted to compare the size of the same-object benefit in the different hand positions. The main effect of hand position and target location was not significant, $Fs (1, 25) < 1$. However, a significant interaction was observed, revealing a same-object benefit far from the hands but a same-object cost near the hands, $F (1, 25) = 7.8$, $p = .01$, $\eta_p^2 = .238$. In other words, when the hands were placed nearby the visual stimuli, participants were poorer at identifying the orientation of the Gabor patch on the cued object ($A' = .964$) than on the uncued object ($A' = .978$). Contrary
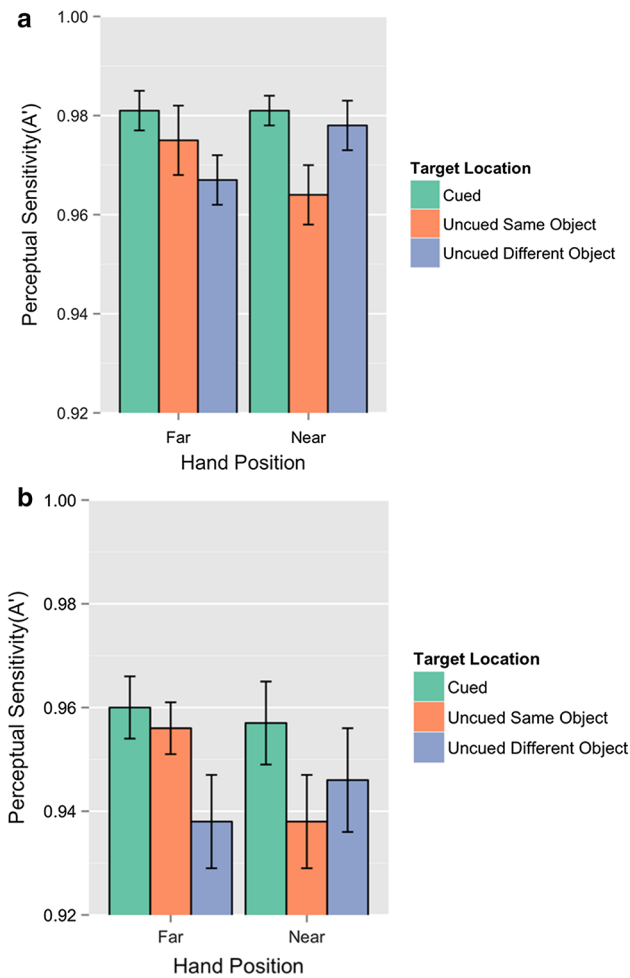
Fig. 4 Perceptual sensitivity (A') as a function of hand position and target location in **a** Experiment 2A and **b** Experiment 2B. *Error bars* represent within-subject standard errors

to this, when the hands were placed far from the visual stimuli, participants were poorer at identifying the orientation of the Gabor patch on the uncued object ($A' = .967$) than on the cued object ($A' = .975$).

Post hoc pairwise comparisons revealed that there was no difference between sensitivity to orientation in the uncued-same-object and uncued-different-object conditions with the far-hand position, $t(25) = 1.154$, $p = .260$, $d = .263$, but sensitivity was better at the uncued-different-object than the uncued-same-object location with the near-hand position, $t(25) = 2.616$, $p = .015$, $d = 536$.

A repeated measures ANOVA using only the cued- and uncued-same-object target locations revealed a significant main effect of target location, $F(1, 25) = 7.833$, $p = .01$, $\eta_p^2 = .239$: Orientation sensitivity was better at the cued location compared to the uncued-same-object. The main effect of hand position, $F(1, 25) = 1.274$, $p = .270$, $\eta_p^2 = .049$, and the interaction, $F(1, 25) = 2.648$, $p = .116$, $\eta_p^2 = .096$, were not significant.

Percentage of error

Table 2 shows the mean percentage of error as a function of hand position and target location. A repeated measures ANOVA using only the uncued target locations showed a significant interaction, with a slight advantage for the cued object when the hands were far and a disadvantage when they were near, $F(1, 25) = 6.049$, $p = .021$, $\eta_p^2 = .195$. However, neither the main effect of hand position, $F(1, 25) < 1$, nor target location, $F(1, 25) = 1.366$, $p = .253$, $\eta_p^2 = .052$, was significant.

Post hoc pairwise comparisons revealed that there was a same-object cost near the hands, $t(25) = 2.816$, $p = .009$,

Table 2 Mean reaction time (RT), and percentage of error in Experiments 2A and 2B

	Hand position	Target location			
		Cued	Uncued-same-object	Uncued-different-object	Same-object benefit
Experiment 2A					
Error (%)	Far	4.33	6.01	7.09	1.08
	Near	4.39	8.05	5.17	−2.88**
RT (ms)	Far	495.64	517.09	529.93	12.84*
	Near	486.50	514.81	521.32	6.51
Experiment 2B					
Error (%)	Far	8.11	11.06	13.46	2.40
	Near	9.01	12.02	10.46	−1.56
RT (ms)	Far	531.51	560.94	564.88	3.94
	Near	542.82	572.73	572.76	.03

The same-object benefit was obtained by subtracting uncued-same-object values from uncued-different-object values

* $p < .05$; ** $p < .01$

$d = .557$. But the object benefit far from the hands was not significant, $t(25) = 1.116$, $p = .275$, $d = .183$.

To examine the spatial cuing effect, a repeated measures ANOVA using only the target locations on the cued object (cued- and uncued-same-object) was conducted and revealed a main effect of target location, $F(1, 25) = 15.345$, $p = .001$, $\eta_p^2 = .380$, with responses more accurate at the cued location compared to the uncued-same-object. The main effect of hand position, $F(1, 25) = 1.035$, $p = .319$, $\eta_p^2 = .040$, and the interaction, $F(1, 25) = 1.310$, $p = .263$, $\eta_p^2 = .050$, were not significant.

RT

RTs for each condition are given in Table 2. A repeated measures ANOVA using only the uncued target locations showed a significant main effect of target position, $F(1, 25) = 5.594$, $p = .026$, $\eta_p^2 = .183$, with RT faster for the uncued-same-object compared to uncued-different-object. Post hoc tests revealed that the difference was reliable only for far-hand posture, $t(25) = 2.807$, $p = .01$, $d = .142$, but not for near-hand posture, $t(25) = 1.116$, $p = .275$, $d = .087$. The main effect of hand position and interaction failed to reach statistical significance, $Fs(1, 25) < 1$.

A repeated measures ANOVA using only the cued- and uncued-same-object target locations revealed a spatial cuing benefit, $F(1, 25) = 47.409$, $p = .000$, $\eta_p^2 = .655$, with RT faster at the cued location. The main effect of hand position, $F(1, 25) < 1$, and the interaction, $F(1, 25) = 1.160$, $p = .292$, $\eta_p^2 = .044$, were not significant.

Experiment 2B

Four participants whose error rate in any condition was above two standard deviations from the mean error rate (>41.25 %) were excluded from further analysis. The average error rate of those four participants was 44.53 % (SD = 10.93) and that of the other participants was 10.68 % (SD = 5.64). For the remaining data, RTs above or below two standard deviations from the mean of each participant were removed from RT analysis (5.14 % of total trials).

A prime

Figure 4b shows perceptual sensitivity as a function of hand position and target location. A hand position × target location repeated measures ANOVA was conducted on the uncued target locations to examine the effect of hand position on the same-object benefit. The main effect of hand position and target location was not significant, $Fs(1, 25) < 1$. A significant interaction between target location and hand position was observed, $F(1, 25) = 5.778$,

$p = .024$, $\eta_p^2 = .188$. Post hoc pairwise comparisons revealed that, when the hands were located far from the visual stimuli, sensitivity was higher for uncued-same-object ($A' = .956$) than uncued-different-object ($A' = .938$) conditions, $t(25) = 2.426$, $p = .023$, $d = .437$. However, when the hands were near to the visual stimuli, there was no difference in sensitivity at uncued-same-object ($A' = .938$) and uncued-different-object ($A' = .946$) locations, $t(25) < 1$.

A repeated measures ANOVA including only the cued- and uncued-same-object locations was conducted to examine the spatial cuing effect. The main effect of target location was significant, $F(1, 25) = 5.273$, $p = .030$, $\eta_p^2 = .174$, with orientation sensitivity better at the cued location compared to the uncued-same-object location. The main effect of hand position, $F(1, 25) = 2.143$, $p = .156$, $\eta_p^2 = .079$, and the interaction, $F(1, 25) = 2.306$, $p = .141$, $\eta_p^2 = .084$, were not significant.

Percentage of error

Table 2 shows the mean percentage of error as a function of hand position and target location. A repeated measures ANOVA using only the uncued target locations was conducted. The main effect of hand position and target location was not significant, $Fs(1, 25) < 1$. However, a significant interaction, $F(1, 25) = 4.343$, $p = .048$, $\eta_p^2 = .148$, was observed, revealing a small object advantage with the far-hand position and a small cost with near hands. Post hoc pairwise comparisons, however, revealed that the same-object benefit was not significant in either the far-hand, $t(25) = 1.865$, $p = .074$, $d = .318$, or near-hand positions, $t(25) = 1.083$, $p = .289$, $d = 168$.

A repeated measures ANOVA as a function of hand position using only the cued object locations showed that the main effect of target location was significant, $F(1, 25) = 9.857$, $p = .004$, $\eta_p^2 = .283$, showing orientation discrimination was more accurate at the cued location compared to the uncued-same-object. The main effect of hand position and the interaction were not significant, $Fs(1, 25) < 1$.

RT

RTs for each condition are given in Table 2. A repeated measures ANOVA including only the uncued target locations failed to find a significant main effect and interaction, $Fs(1, 25) < 1$, suggesting that there was no influence of hand position on the same-object benefit.

A repeated measures ANOVA including cued- and uncued-same-object conditions showed a significant main effect of target location, $F(1, 25) = 42.855$, $p < .001$,

$\eta_p^2 = .632$, with RT faster at the cued location compared to the uncued-same-object location. The main effect of hand position, $F(1, 25) = 1.285$, $p = .268$, $\eta_p^2 = .049$, and the interaction, $F(1, 25) < 1$, were not significant.

Discussion

We observed a reduced and reversed same-object benefit in the near-hand space relative to the far-hand space in Experiments 2A and 2B. Perceptual sensitivity was generally higher when the target appeared at an uncued location in the cued object than in the uncued object when the hands were located far away from the visual stimuli, consistent with earlier findings (e.g., Egly et al. 1994). The result implies that cueing one end of an object increases perceptual sensitivity in the space within the cued object. However, the same-object benefit disappeared when the hands were placed nearby the visual stimuli. Moreover, in the near-hand space, perceptual sensitivity was even worse at the uncued-same-object location than at the uncued-different-object location in Experiment 2A, and the same pattern was found in Experiment 2B.

General discussion

In three experiments, we examined object-based attentional selection near to and far from the hands. As has been shown previously (e.g., Egly et al. 1994), there was an advantage to detect targets on cued objects when the hands were far from the stimuli. However, that same-object benefit disappeared (Experiments 1 and 2B) or became a cost (Experiment 2A) when the hands were held close to the stimuli. Overall, the findings show impaired object-based visual processing in the near-hand space.

Our results are informative regarding the changes in vision that take place near the hands. Several studies have suggested that there is enhanced processing along the magnocellular pathway and reduced processing on the parvocellular pathway for stimuli near the hands. Given that the magnocellular pathway is sensitive to coarser detail than the parvocellular pathway, it is not unexpected that the binding together of object features would be reduced in the near-hand space, consistent with our results.

Many researchers have assumed that near-hand changes in vision arise because stimuli near the hands are potential candidates for manipulation (e.g., Abrams et al. 2008). According to this argument, action-centered mechanisms may be automatically engaged to evaluate near-hand stimuli. Nevertheless, studies that have specifically examined object processing in response to actual hand movements have found a complex pattern of results. For example, Linnell et al. (2005) found a reduced object-based effect in a pointing task, whereas Fischer and Hoellen (2004) found an enhanced object-based effect in a grasping task. Based on the present results, we can conclude that hand-nearness, if it activates action-related mechanisms, may cause processing similar to that which occurs during pointing movements, as opposed to grasping movements.

We also examined the spatial cueing effect near the hands. In each experiment, the spatial cueing effect was numerically larger in the near-hand space compared to the far-hand space, but the differences were not statistically significant. The absence of a significant difference in the spatial cueing effect might be explained by the fact that the spatial cue in the current paradigm was very salient and may have been too strong to be further amplified by the near-hand position. Nevertheless, the slight increments in spatial cueing suggest the possibility that not only was object-based perception reduced, but also space-based perception could possibly be enhanced near the hand.

In Experiment 2A, we observed a same-object cost instead of a benefit in the near-hand space. A same-object cost has also been reported in some other studies (Davis 2001; Davis and Holmes 2005). For example, Davis (2001) showed a same-object cost when the target and rectangles were simultaneously presented. His interpretation was that when the target and object were presented at the same time, processing would be biased in favor of the faster magnocellular pathway. Furthermore, he proposed that magnocellular mechanisms were responsible for binding together features between objects (see also Humphreys 1998). Such an occurrence might be expected to lead to a benefit for targets on the uncued object, as we observed in Experiment 2A.

Lastly, in the present study, we observed reduced contrast sensitivity in the uncued end of the cued object when the hands were nearby the display (Experiment 2A). Contrast sensitivity as tested in the present study is believed to reflect processing early in the visual system (Liu et al. 2007). Thus, at least some of the changes in vision near the hands appear to occur early in processing. A similar conclusion was reached by Cosman and Vecera (2010). They showed that placement of a hand changed figure-ground assignment—something that is also believed to occur early in visual processing. In their experiments, participants viewed an ambiguous two-region figure-ground stimulus when either their hand or a wooden dowel was placed nearby one of the two regions. Participants were more likely to perceive the region located nearby the hand as 'figure' when the hand was used as a visual anchor (but a similar pattern was not observed for the dowel). They concluded that placing a hand near an image causes preferential attentional processing to the region nearby the hand. In the present study, a reduced and reversed same-object benefit was also found in contrast sensitivity, suggesting that

hand position influences object-based perception in early vision.

In conclusion, we have shown that hand proximity influences object-based perceptual grouping. In particular, the present results revealed an impaired or reversed same-object benefit in the near-hand space. While the results are consistent with an enhancement of processing on the magnocellular pathway, as a number of researchers have proposed, we cannot offer any definitive conclusions regarding the underlying neural mechanisms. Nevertheless, the present study provides a better understanding of how people group and segment the visual world nearby the hands.

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