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Switching between global and local scopes of attention is resisted near the hands

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Recently, several changes in perception, attention, and visual working memory have been reported when stimuli are near to compared to far from the hands, suggesting that such stimuli receive enhanced scrutiny. A mechanism that inhibits the disengagement of attention from objects near the hands, thus forcing a more thorough inspection, has been proposed to underlie such effects. Up until now, this possibility has been tested only in a limited number of tasks. In the present study we examined whether changes in one's global or local attentional scope are similarly affected by hand proximity. Participants analysed stimuli according to either their global shape or the shape of their constituent local elements while holding their hands near to or far from the stimuli. Switches between global and local processing were markedly slower near the hands, reflecting an attentional mechanism that compels an observer to more fully evaluate objects near their hands by inhibiting changes in attentional scope. Such a mechanism may be responsible for some of the changes observed in other tasks, and reveals the special status conferred to objects near the hands.

Keywords: Selective attention; Visual attention; Embodied Cognition; Global/ Local Processing; Task Switching.

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Recent studies have shown that vision is influenced by the proximity with which people hold their hands to objects being inspected. Hand proximity improves perceptual sensitivity (Schendel & Robertson, 2004) and affects figure–ground assignment (Cosman & Vecera, 2010); it biases the allocation of visual attention, with nearby objects receiving attentional prioritization (Reed, Betz, Garza, & Roberts, 2010; Reed, Grubb, & Steele, 2006); it inhibits disengagement during visual search (Abrams, Davoli, Du, Knapp, & Paull, 2008; Davoli & Abrams, 2009); and yields improved visual working memory (Tseng & Bridgeman, 2011) relative to objects further from the hands. These changes in turn have consequences for higher order processes such as how people remember complex visual patterns (Davoli, Brockmole, & Goujon, 2012) and process semantic information (Davoli, Du, Montana, Garverick, & Abrams, 2010). Importantly, the effects of hand proximity are not attributable to tradeoffs in effort, comfort, response location, or hand-visibility that may emerge when one takes hold of viewed material (Abrams et al., 2008; Davoli & Abrams, 2009; Davoli et al., 2010; Reed et al., 2006). Rather, altered processing near the hands is thought to reflect the adaptive importance of thoroughly evaluating nearby objects, given that the hands afford direct interaction with such objects (Abrams et al., 2008; Graziano & Cooke, 2006).

These perceptual and attentional phenomena reveal the importance of evaluating objects near the hands, perhaps because they are candidates for interaction. However, the nature of one's interaction with an object may take on one of many different forms. In some cases, for example, efficient behaviour might benefit from an attentional scope that enables the evaluation of an object's global aspects (e.g., "seeing the forest"), whereas in other situations detailed features of an object may be more important (e.g., "seeing the trees"). Thus, the attentional scope of the analysis required of an object depends on the task at hand. Although one can voluntarily switch between global and local scopes of attention, when analysing objects near the hands—given the importance of thoroughly evaluating these objects—it would be beneficial if such volitional switches were delayed in order to ensure complete analysis within a selected scope. Such an occurrence would be consistent with prior evidence showing that the spatiotemporal dynamics of attention are slowed near the hands (Abrams et al., 2008; Davoli & Abrams, 2009). Nevertheless, this possibility has yet to be tested, and is the objective of the present study. To accomplish this, we assigned participants a task that required a specific attentional scope and then measured the ease with which they could adopt an alternative scope. Consistent with our prediction, participants were indeed slower to switch attentional scope for objects near the hands.

EXPERIMENT 1

In Experiment 1, participants attended to either the wholistic (global) form or the smaller (local) elements of two hierarchical shapes (cf. Navon, 1977; Pomerantz, 1983; Figure 1A–D) presented in sequence on each trial (denoted S1 and S2) either near to (the hands-near condition) or far from (the hands-far condition) the hands. While attending to these shapes, participants switched between global and local processing by having to identify the global shape of S1 and the local elements within S2, or vice versa. In order to contrast the extent to which shifts of attentional scope could be completed near to or far from the hands, we varied the elapsed time between the response to the first stimulus and the onset of the second stimulus (the response-to-stimulus interval; RSI). It is known from a variety of paradigms that preparation for the second of two tasks occurring in brief succession is a time-consuming process as attention must be disengaged from one task and reengaged on another (Brockmole, Carlson, & Irwin, 2002; Monsell, 2003; Robertson, 1996; Robertson, Egly, Lamb, & Kerth, 1993; Rogers & Monsell, 1995; Ward, 1982). As the time between tasks increases, responses associated with the second task tend to be faster as more preparation can be completed in advance. Thus, we expected responses to S2 to decrease as the RSI increased, but for this to be modulated by hand position. Specifically, if switches between attentional scopes are slowed near the hands, then longer

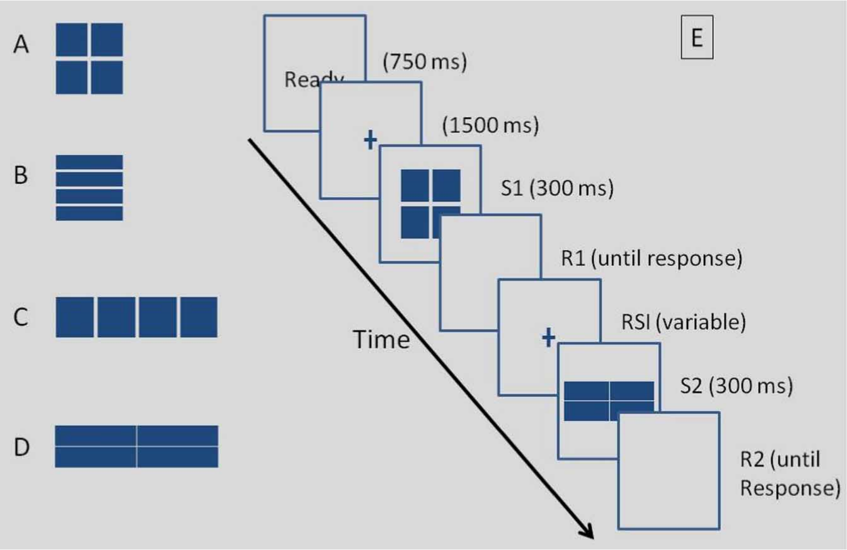

Figure 1. Panels A–D depict the hierarchical figures that were used as the experimental stimuli. Panel E shows the events and timings of a sample trial. To view this figure in colour, please see the online issue of the Journal.

RSIs would be required in the hands-near compared to the hands-far condition in order to achieve equivalence in response times to S2.

Method

Participants. Twenty experimentally naïve University of Notre Dame undergraduates participated in exchange for course credit or monetary compensation.

Stimuli and apparatus. Stimuli are illustrated in Figure 1A–D (cf. Brockmole et al., 2002; Kimchi & Palmer, 1985) and represent the factorial combination of four local elements (squares or rectangles) to form a global shape (square or rectangle). In terms of local elements, squares subtended 7.5 cm horizontally and vertically and rectangles subtended 16 cm horizontally and 3.5 cm vertically. In terms of global forms, squares subtended 16 cm horizontally and vertically, and rectangles subtended 33 cm horizontally and 7.5 cm vertically. All stimuli were drawn in dark blue against a light grey background on a 17-inch CRT display with a refresh rate of 100 Hz. Participants viewed the stimuli at an unconstrained distance of approximately 40 cm. Responses were made by pressing one of two response buttons. In the hands-near condition, the response buttons were affixed to either side of the visual display and aligned with its vertical centre. In the hands-far condition, the response buttons were affixed to a lightweight board which participants held in their laps.

Design and procedure. Hand posture relative to the display was a between-subjects manipulation with 10 participants randomly assigned to each posture. The remaining aspects of the experimental design were the same for both groups. During the course of a trial, participants saw two stimuli (S1, S2) and made a response to each (R1, R2). A sample trial is shown in Figure 1E. A trial began with a "Ready" prompt (750 ms), followed by a central cross. After 1500 ms, the cross was replaced with S1. After 300 ms, S1 was removed and the screen was blank until R1. Following R1, the central cross was then presented again for a variable amount of time (0, 32, 64, 100, 132, 164, 200, or 232 ms), followed by the presentation of S2. We refer to this delay as the RSI. After remaining visible for 300 ms, S2 was removed and the screen remained blank, during which participants provided R2. A 1000 ms intertrial interval followed R2.

The experiment consisted of 256 trials divided evenly into two blocks. Within each block, crossing the 16 possible pairwise combinations of stimuli with the eight RSIs yielded 128 unique trials. In one block, participants first identified the local elements of S1 and then the global form of S2. In the other block, they first responded to the global form of S1 and then the local elements of S2. The order of blocks was counterbalanced across participants. During the experiment, any trial in which the participant provided any incorrect response was recycled by inserting it back into a random position in the trial sequence.[1]

Results and discussion

Preliminary mixed model analyses of variance (with hand posture as the between-subjects factor) showed that response times to the global shape or the local elements of a stimulus did not differ from one another, nor did this factor (i.e., attentional scope) interact with hand posture (or any other factor). Specifically, for R1 there was no main effect of attentional scope (global vs. local) on response time, $F < 1$, nor was there an interaction between attentional scope and hand posture (hands-near vs. hands-far), $F = 1.99$, $p = .18$. The same was true for R2, where there was no main effect of attentional scope, $F = 1.72$, $p = .21$ and no interactions involving attentional scope and hand posture (all Fs < 1). For ease of exposition, we collapse across attentional scope in the analyses presented next.[2]

The analysis of R1 was collapsed across RSI because the RSI manipulation occurred after R1 on each trial. A marginal effect of posture was observed, with responses being somewhat faster in the hands-near ($M = 596.31$, $SD = 66.81$ ms) compared to the hands-far ($M = 658.56$ ms, $SD = 82.63$) condition, $t(18) = 1.85$, $p = .08$.

R2 was submitted to a 2 (hand posture) × 8 (RSI) mixed model analysis of variance (ANOVA). The main effect of hand posture was not significant, $F(1, 18) < 1$. As expected, response times decreased as RSI increased, $F(7, 126) = 21.32$, $p < .001$, $\eta_p^2 = .54$, indicating that participants benefited from having more time to prepare for S2 (cf. Brockmole et al., 2002; Monsell, 2003). Critically, the effect of RSI was not equivalent across hand postures as evidenced by an interaction between hand posture and RSI, $F(7, 126) = 2.95$, $p = .007$, $\eta_p^2 = .14$. As is shown in Figure 2, at brief RSIs, RTs were slower in the hands-near compared to the hands-far condition, but at the longer RSIs the RTs were equivalent. Linear regression models indicated that an additional 185 ms was necessary in the hands-near condition

[1] On average, 56 trials were recycled in the hands-near condition and 40 trials were recycled in the hands-far condition. These values did not differ, $t(18) < 1$.

[2] For Experiment 1, response times to the global shape and local elements of S1 averaged 655 ms ($SE = 27$ ms) and 665 ms ($SE = 24$ ms), respectively, in the hands-far condition, and 611 ms ($SE = 27$ ms) and 584 ms ($SE = 24$ ms), respectively, in the hands-near condition. Response times to the global shape and local elements of S2 averaged 580 ms ($SE = 24$ ms) and 571 ms ($SE = 24$ ms), respectively, in the hands-far condition, and 610 ms ($SE = 27$ ms) and 583 ms ($SE = 24$ ms), respectively, in the hands-near condition.

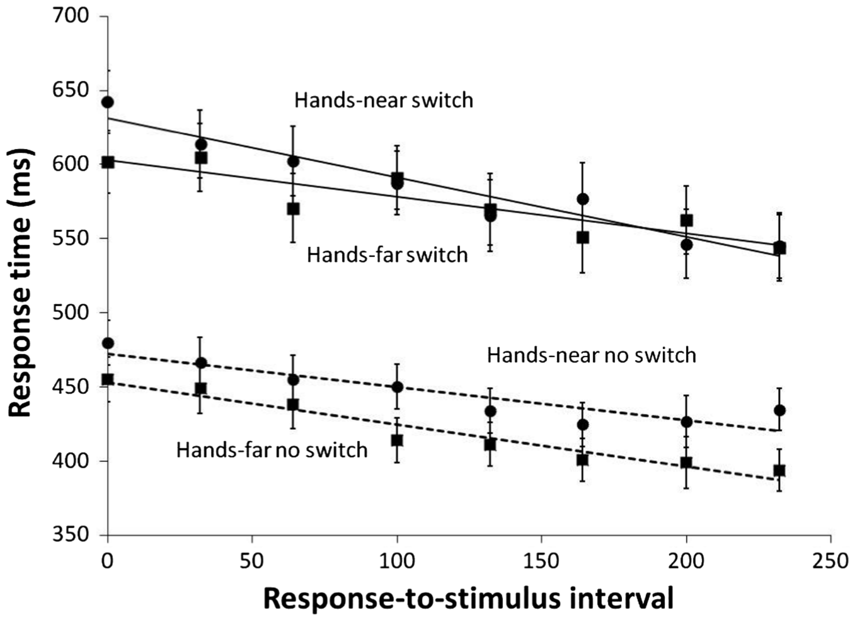

Figure 2. Mean RTs for R2 at each RSI for the hands-near and hands-far conditions of Experiments 1 (switch) and 2 (no switch). Error bars represent 1 standard error of the mean. Lines represent best-fitting straight lines.

($y = -0.40x + 631.09$) to produce similar response times as observed in the hands-far condition ($y = -0.25x + 602.98$).

This pattern of results suggests that the hands-near posture caused delayed switches between global and local processing compared to when the hands were held far. Note that the present results cannot be explained by the hands-near posture merely slowing response times. This is because there was no main effect of hand posture on response times for S2, and response times to S1 were actually somewhat shorter in the hands-near posture. Overall, then, the data are consistent with the hypothesis that placing the hands near to objects slows switches between attentional scopes.

EXPERIMENT 2

Although the results of Experiment 1 appear to demonstrate slowed switches between attentional scopes near the hands, it is possible that participants were instead slower to reorient their attention more generally in order to evaluate the second stimulus on each trial. The purpose of Experiment 2, then, was to test whether the effects observed in Experiment 1 were specific to switches of attentional scope. To do this, we repeated the procedures used previously, except that observers here identified either the global shape of both stimuli or the local elements of both stimuli. If indeed it is switching between attentional scopes, and not the reorientation of attention to a new stimulus, that is slowed near the hands, then performance in the hands-near and hands-far conditions should be equivalent.

Method

Participants. Twenty new experimentally naïve University of Notre Dame undergraduates participated in exchange for course credit or monetary compensation.

Stimuli, apparatus, design, and procedures. All aspects of the experimental method were the same as in Experiment 1, except that in separate blocks of trials observers identified the global form of both stimuli or the local elements of both stimuli.[3] The order of these blocks was counterbalanced across participants.

Results and discussion

Analyses paralleled those conducted in Experiment 1.[4] Mixed model ANOVAs (with hand posture as the between-subjects factor) showed that for R1 there was no main effect of attentional scope, $F = 1.08$, $p = .31$, and the interaction between scope and hand posture was not significant, $F < 1$. For R2, the main effect of attentional scope was again not significant, $F < 1$, and no interactions involving scope and hand posture were significant (all Fs < 1). Thus, as in Experiment 1, we collapse across attentional scope in the following analyses. For R1, no effect of hand posture was observed, $t(18) = 1.02$, $p = .32$. Results for R2 are shown in Figure 2. For R2, the main effect of hand posture was also not reliable, $F(1, 18) = 1.64$, $p = .22$, $\eta_p^2 = .08$. Response times decreased as RSI increased, $F(7, 126) = 26.61$, $p < .001$, $\eta_p^2 = .60$, indicating that participants benefited from having more time to prepare for S2 even though a switch of attentional scope was not

[3] On average, 17 trials were recycled in the hands-near condition and 15 trials were recycled in the hands-far condition. These values did not differ, $t(18) < 1$.

[4] For Experiment 2, response times to the global shape and local elements of S1 averaged 506 ms ($SE = 31$ ms) and 483 ms ($SE = 27$ ms), respectively, in the hands-far condition, and 538 ms ($SE = 31$ ms) and 535 ms ($SE = 27$ ms), respectively, in the hands-near condition. Response times to the global shape and local elements of S2 averaged 420 ms ($SE = 18$ ms) and 423 ms ($SE = 14$ ms), respectively, in the hands-far condition, and 443 ms ($SE = 18$ ms) and 451 ms ($SE = 14$ ms), respectively, in the hands-near condition.

necessary (cf. Brockmole et al., 2002; Niemi & Näätänen, 1981). Critically, hand posture did not modulate the effect of RSI, $F(7, 126) = 1.02$, $p = .42$, $\eta_p^2 = .05$. Thus, the effects of hand posture observed in Experiment 1 were specific to switching between attentional scopes, and not to more general reorientation of attention to a subsequent stimulus, as the methods used in Experiment 2 were otherwise identical. We confirmed this contrast by observing a three-way interaction through a 2 (experiment) × 2 (hand posture) × 8 (RSI) mixed model ANOVA, $F(7, 252) = 3.02$, $p = .01$, $\eta_p^2 = .08$.

GENERAL DISCUSSION

Recent evidence has revealed that visual perception, attention, and working memory are altered for objects near the hands in ways that indicate enhanced and prolonged processing of such objects relative to more distant ones (e.g., Abrams et al., 2008; Cosman & Vecera, 2010; Reed et al., 2006; Tseng & Bridgeman, 2011). Interpretations of these effects have centred on the relative importance of nearby objects as candidates for interaction (e.g., Abrams et al., 2008; Graziano & Cooke, 2006). Altered processing near the hands may allow one to acquire visual information that may help with interaction such as a nearby object's size and orientation (Abrams et al., 2008). Furthermore, decisions to proceed with or reject interaction are often based on subtle differences in visual detail of similar objects (e.g., which of two fruits should be consumed), and thus awarding these objects more rigorous and prolonged scrutiny would presumably prompt the better decision. Although altered processing near the hands is thought (e.g., Cosman & Vecera, 2010; Reed et al., 2006; Schendel & Robertson, 2004) to reflect a system of bimodal neurons that specifically represents hand-space (e.g., Graziano, Hu, & Gross, 1997; Murata, Gallese, Luppino, Kaseda, & Sakata, 2000), the cognitive mechanism that fosters such alterations is unclear. Abrams et al. (2008) proposed that hand proximity engages a mechanism that facilitates prolonged evaluation of nearby objects. Their conclusion was supported by demonstrations of inhibited disengagement of spatial and temporal attention near the hands. Here, we considered whether another type of attentional shift—namely a switch between global and local scopes of processing—would similarly be slowed near the hands, and found evidence in support of that notion. Thus, the present study extends the earlier results by showing that not only are the spatiotemporal dynamics of attention slowed near the hands, but so too are volitional switches between attentional scopes. Taken together, these findings suggest that hand proximity engages a mechanism that allows attention to "lock in" in several ways during the processing of objects. That in turn may yield facilitations in object-oriented perception (Cosman & Vecera, 2010), visual working memory (Tseng & Bridgeman, 2011), and visual learning (Davoli et al., 2012).

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