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Grasp Posture Alters Visual Processing Biases Near the Hands

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Abstract

Observers experience biases in visual processing for objects within easy reach of their hands; these biases may assist them in evaluating items that are candidates for action. I investigated the hypothesis that hand postures that afford different types of actions differentially bias vision. Across three experiments, participants performed global-motion-detection and global-form-perception tasks while their hands were positioned (a) near the display in a posture affording a power grasp, (b) near the display in a posture affording a precision grasp, or (c) in their laps. Although the power-grasp posture facilitated performance on the motion-detection task, the precision-grasp posture instead facilitated performance on the form-perception task. These results suggest that the visual system weights processing on the basis of an observer's current affordances for specific actions: Fast and forceful power grasps enhance temporal sensitivity, whereas detail-oriented precision grasps enhance spatial sensitivity.

Keywords

embodied perception, visual processing

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A growing variety of neurophysiological, neuropsychological, and psychophysical evidence suggests that people see objects that are within peripersonal space—objects they can easily reach with their hands—differently than they do objects outside their reach. Observers experience changes in visual processing of objects near their hands, including alterations in perception (Cosman & Vecera, 2010), attention (e.g., Abrams, Davoli, Du, Knapp, & Paull, 2008; Reed, Grubb, & Steele, 2006), and memory (Thomas, Davoli, & Brockmole, 2013; Tseng & Bridgeman, 2011; for reviews, see Brockmole, Davoli, Abrams, & Witt, 2013, and Tseng, Bridgeman, & Juan, 2012). Objects near the hands afford immediate interaction, creating a potential need to evaluate items that are candidates for action by integrating visual information with spatial, tactile, and proprioceptive representations. Changes in processing of visual stimuli occur specifically within the hands' grasping space (Reed, Betz, Garza, & Roberts, 2010) and drop off as the distance between the hands and a visual stimulus increases (Tseng & Bridgeman, 2011). These processing changes may reflect the visual system's adaptive sensitivity to behavioral contexts (e.g., Brockmole et al., 2013; Graziano & Cooke, 2006).

Although researchers investigating altered vision near the hands have proposed action-based explanations for why these changes occur, little research has explored how the hands' potential to engage in specific actions mediates visual-processing biases. Most of the literature on near-hand effects focuses on how the presence of the hands in general influences visual processing, but researchers have investigated only a limited range of hand postures and action affordances. Typically, observers' performance on a visual task under a hands-near condition is compared against performance in a hands-far condition (e.g., Abrams et al., 2008). In virtually all of this literature, observers in the hands-near conditions position their hand(s) in a manner that affords power-grasp actions (Fig. 1a): The fingers function as a unit that can curl around an object to secure it against the palm. The power-grasp posture affords actions that are fast and

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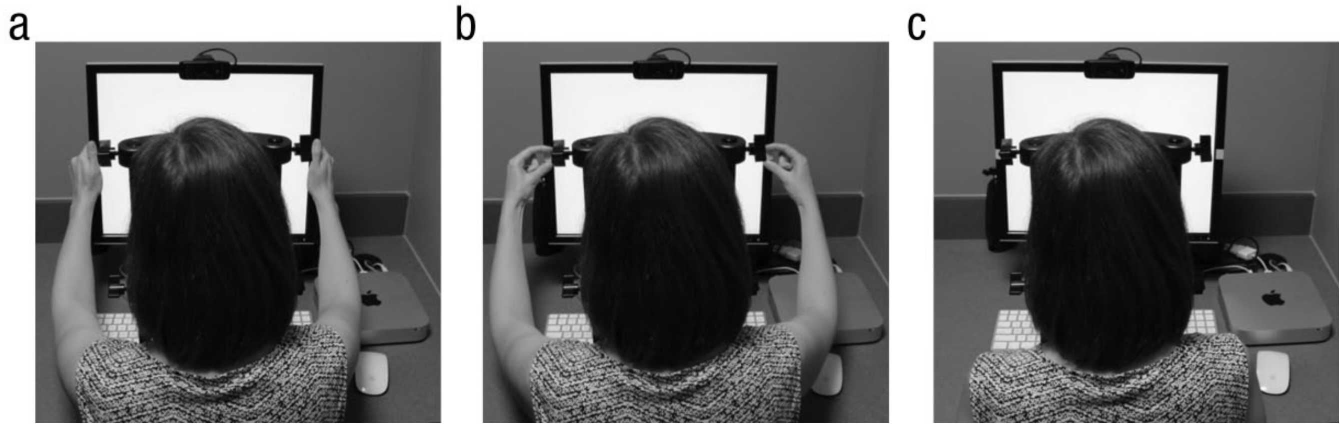

Fig. 1. Hand postures. Demonstrated are (a) the power-grasp posture, (b) the precision-grasp posture, and (c) the hands-far control posture (i.e., the participant's hands are in her lap).

forceful (e.g., catching a ball) but do not necessarily require high precision.

Given an action-based account of altered vision near the hands, it is unsurprising that this power-grasp hands-near posture is associated with increased temporal but decreased spatial visual sensitivity compared with hands-far conditions—evidence suggests that information processing near hands positioned for a power grasp may be biased toward increased contributions from the magnocellular (M) visual pathway, whereas processing away from the hands may reflect stronger contributions from the parvocellular (P) pathway (e.g., Abrams & Weidler, 2014; Goodhew, Gozli, Ferber, & Pratt, 2013; Gozli, West, & Pratt, 2012). However, it is unclear whether differences in how the hands are positioned—and the actions these positions afford—differentially bias visual processing. Does readiness to perform one action rather than another have the potential to shape the way people see the world, leading to affordance-specific alterations in visual sensitivity?

In addition to the oft-investigated power grasp, people also frequently perform precision grasps. People typically adopt one of these two postures to grip nearby objects—flexing the fingers around an object to hold it against the palm in a power grasp or securing an object between the pads of the thumb and fingers in a precision grasp (Napier, 1956). Although a precision-grasp posture (Fig. 1b) affords actions that bring objects into contact with areas of the hand with higher tactile spatial acuity, which aids in delicate and detail-oriented work (e.g., threading a needle), a power-grasp posture instead affords actions that bring objects into contact with less sensitive areas of the hand that enable a more forceful grip (Craig, 1999; Craig & Lyle, 2001; Johansson & Vallbo, 1979). Observers represent objects according to whether they afford power or precision grasps (Tucker & Ellis, 2001, 2004), and viewing pictures of hands in these two different grasp postures automatically biases attention to grasp-congruent objects in a display (Fischer, Prinz, & Lotz, 2008). I hypothesized that the visual system would likewise distinguish between power-grasp and precision-grasp postures in near-hand visual processing biases.

If positioning the hands to afford a particular action biases processing of action-relevant information near the hands, different hand postures should differentially affect visual task performance. Recent evidence shows that observers are facilitated in rapidly detecting targets that appear near a hand that is positioned to afford a power grasp (e.g., Reed et al., 2006, 2010), but this facilitation is eliminated if the hand is instead positioned to afford a precision grasp (Thomas, 2013). However, this finding does not necessarily imply that viewing stimuli in the near-hand space in a precision-grasp posture will have no consequences for visual processing. The precision-grasp posture may introduce biases that are ill suited to meet the demands of rapidly detecting targets but could benefit more detail-oriented tasks that are compatible with the precise actions this grasp posture affords. If specific grasp postures facilitate processing of visual information that is relevant to actions that the postures afford, then a power-grasp posture should enhance temporal sensitivity—information that aids in catching a ball—whereas a precision-grasp posture should enhance more fine-grained analysis of spatial properties—information useful when threading a needle.

To investigate this hypothesis, across three experiments, I asked participants to perform a global-motion-detection task and a global-form-perception task that research has linked to M and P pathway function, respectively (e.g., McKendrick, Badcock, & Morgan, 2005). In each experiment, participants performed these tasks under two different hand-posture conditions: hands-near

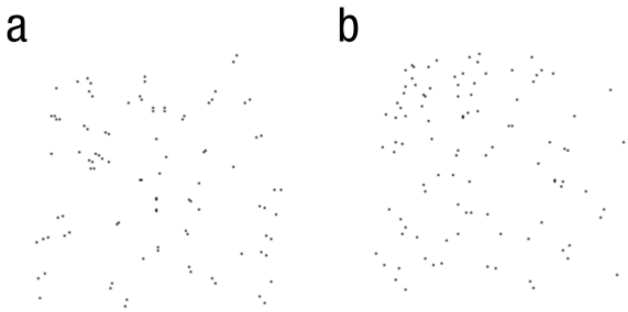

Fig. 2. Example of form-perception stimuli: (a) radial signal dots and (b) concentric signal dots. In (a), 80% of the dots are part of the pattern, and the remaining 20% are placed randomly. In (b), 40% of the dots are part of the pattern, and the remaining dots are placed randomly.

power grasp versus hands-far control (Experiment 1), hands-near precision grasp versus hands-far control (Experiment 2), hands-near power grasp versus hands-near precision grasp (Experiment 3a), and hands-far power grasp versus hands-far precision grasp (Experiment 3b).[1] Positioning the hands near the display in a power-grasp posture enhanced motion detection, but positioning the hands near the display in a precision-grasp posture instead aided form perception. The results of these experiments suggest that the visual system weights processing on the basis of an observer's current affordances for specific actions.

Method

Overview of the tasks

All participants performed both a global-motion-detection task and a global-form-perception task (modified from McKendrick et al., 2005). Tasks were presented on a monitor set to a resolution of 1,024 × 768 pixels at a refresh rate of 60 Hz. Participants performed both tasks while their chins were stabilized on a chinrest positioned 36 cm from the display. For each task, participants viewed an array of 100 one-pixel black dots presented in a 150- × 150-pixel area in the center of a white background.

In the motion-detection task, participants viewed an eight-frame motion sequence of dots randomly positioned within the central area. Each frame appeared for 50 ms, for a total of 400 ms of viewing time per trial. On each frame transition, a portion of signal dots shifted one pixel in the signal direction (i.e., left or right), which was randomly determined on each sequence. The remaining portion of noise dots shifted one pixel in random directions. To minimize local motion cues, individual dot locations were randomly determined every two frames, which prevented participants from tracking individual dots across the entire motion sequence. If the programmed displacement moved dots outside of the central presentation area, the dots were repositioned on the opposite side of the presentation area for the next frame.

After the presentation of each motion sequence, participants were asked to say whether the primary global motion was to the left or to the right. An experimenter sitting next to the participant but unable to see the display recorded these responses using a keyboard. I used a three-down, one-up staircase procedure to determine individual participants' motion thresholds. Initially, 80% of the dots in the display moved in the signal direction. The percentage of signal dots decreased by 8 percentage points after each correct response until participants made an incorrect response. In cases in which a participant's initial response was incorrect, the percentage of signal dots increased by 8 percentage points. After the first reversal in the pattern of signal dots (i.e., the first change from increasing to decreasing levels of noise or vice versa), the percentage of signal dots decreased by 8 percentage points after three correct responses and increased by 8 percentage points after a single incorrect response. After the third reversal, the percentage of signal dots decreased by 4 percentage points after three correct responses and increased by 4 percentage points after an incorrect response. After the fifth reversal, the percentage of signal dots decreased or increased by 2 percentage points according to the same rules. A block of motion-sequence trials terminated after a participant went through eight reversals. A participant's motion coherence threshold for a block was determined by taking the mean percentage of signal dots present at the final four reversals in that block.

In the global-form-perception task, participants viewed a static array of dots positioned within the central area for 400 ms. For each trial, a proportion of signal dots were arranged in Glass patterns (Glass, 1969) by taking pairs of dots placed at random and orienting them in either a radial or concentric arrangement (Fig. 2). The arrangement of the signal dots into radial or concentric structures was randomized across trials. The remaining dots in the display were randomly placed noise dots.

After each presentation, participants told the experimenter whether they had perceived a radial or concentric global percept, and the experimenter recorded this response using a keyboard. I determined form-perception thresholds using the same modified three-down, one-up staircase procedure used for the global motion task.

Experiment 1

Forty-six volunteers[2] from the North Dakota State University (NDSU) Psychology Department participant pool took part in return for course credit. All participants had normal or corrected-to-normal vision. Participants in

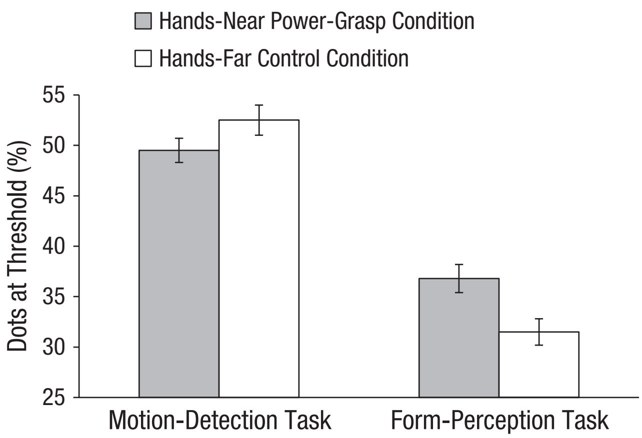

Fig. 3. Results from Experiment 1: mean percentage of signal dots present at the motion-coherence threshold in the motion-detection task and at the form-coherence threshold in the form-perception task. The results are shown separately for the two hand-posture conditions. Error bars represent ±1 *SEM*.

the first experiment performed the motion-detection and form-perception tasks under two different hand postures: the standard hands-near power-grasp posture (Fig. 1a) and a hands-far control posture (Fig. 1c). In the power-grasp posture, participants grasped the display in both hands. They placed the bases of their thumbs over tape indicators on either side of the display (ensuring similar positioning across participants) and curled their fingers around the back of the display, bringing the palms of their hands into contact with the display edges. In the hands-far control posture, participants were instructed to place their hands loosely in their laps. Participants performed eight blocks of the motion-detection task and eight blocks of the form-perception task; the order of the tasks was counterbalanced. They adopted the hands-near power-grasp posture for half of the blocks in each task and the hands-far control posture for the other half of blocks. Written instructions at the beginning of each block indicated which posture participants should adopt, and the experimenter collecting responses ensured that participants maintained the appropriate posture throughout each block. The order of postures was randomized across blocks. The first block for each posture in a task served as practice, and data for this block were not recorded.

Experiment 2

Another 46 volunteers from the NDSU participant pool, none of whom participated in Experiment 1, took part in Experiment 2 in return for course credit. The participants had normal or corrected-to-normal vision. The procedure of Experiment 2 was very similar to that of Experiment 1, except that the hands-near posture used by participants was a precision grasp rather than a power grasp (Fig. 1b). In this precision-grasp posture, participants placed the thumb and forefinger of each hand on either side of the display such that they "pinched" the tape indicators, again ensuring similar positioning across participants. Participants' remaining fingers curled into their palms, which prevented them from making contact with the display edges at any location other than at the thumbs and forefingers. As in Experiment 1, the participants used the hands-far control posture in half of the blocks.

Experiment 3a

Forty-six NDSU volunteers who had not participated in the previous experiments took part in Experiment 3a in return for course credit. These participants reported normal or corrected-to-normal vision. Experiment 3a followed the procedure of the preceding two experiments, but instead of performing the threshold tasks under one hands-near condition and one hands-far condition, participants in this experiment adopted the hands-near power-grasp posture in half of the blocks and the hands-near precision-grasp posture in the remaining blocks.

Experiment 3b

An additional 46 NDSU volunteers with normal or corrected-to-normal vision who had not participated in any of the previous experiments took part in Experiment 3b in return for course credit. Experiment 3b followed the same procedure as the previous experiments, but participants in this experiment adopted the power- and precision-grasp postures while their hands were in their laps, away from the display.

Results

Experiment 1

Figure 3 displays the mean percentage of signal dots present at the motion-coherence and form-coherence thresholds, averaged across the final four blocks of the motion-detection and form-perception tasks, respectively, in the hands-near power-grasp condition and the hands-far control condition in Experiment 1. I submitted participants' thresholds under the different conditions to a 2 × 2 within-subjects analysis of variance (ANOVA) with factors of task (motion detection, form perception) and hand posture (hands-near power grasp, hands-far control). This analysis revealed a main effect of task, $F(1, 45) = 12.71$, $p = .001$, $\eta_p^2 = .22$, as well as a significant interaction between task and hand posture, $F(1, 45) = 7.00$, $p = .016$, $\eta_p^2 = .12$. The main effect of hand posture was not significant ($p > .50$).

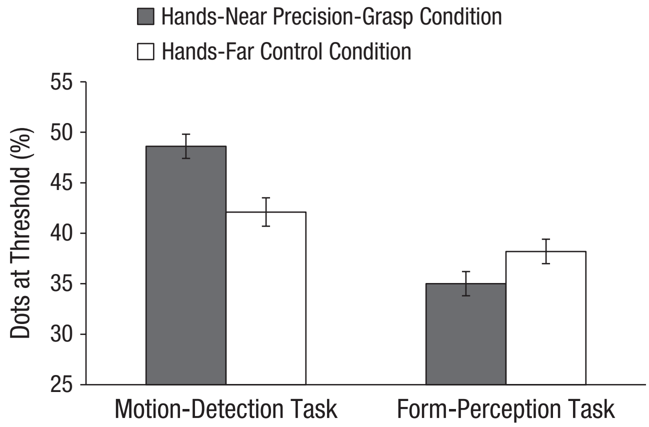

Fig. 4. Results from Experiment 2: mean percentage of signal dots present at the motion-coherence threshold in the motion-detection task and at the form-coherence threshold in the form-perception task. The results are shown separately for the two hand-posture conditions. Error bars represent ±1 *SEM*.

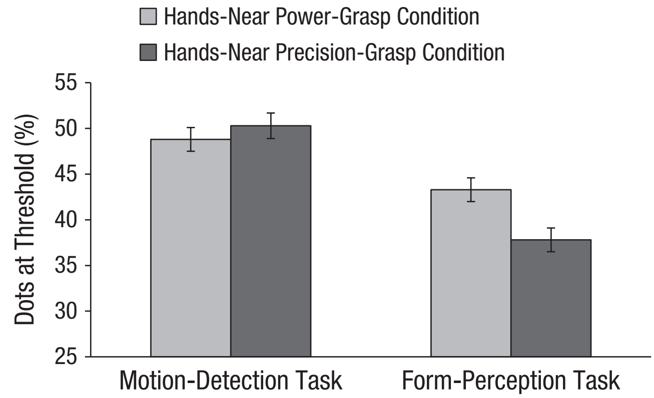

Fig. 5. Results from Experiment 3a: mean percentage of signal dots present at the motion-coherence threshold in the motion-detection task and at the form-coherence threshold in the form-perception task. The results are shown separately for the two hand-posture conditions. Error bars represent ±1 *SEM*.

Planned pairwise comparisons confirmed that hand posture differentially influenced performance on the form-perception and motion-detection tasks: Participants tended to have lower thresholds in the form-perception task (i.e., they were able to distinguish between radial and concentric patterns with a smaller percentage of signal dots than in the motion-detection task) when their hands were far from the display than when they held their hands near the display in a power-grasp posture, $t(45) = -2.14$, $p = .038$. In addition, performance on the motion-detection task was worse than performance on the form-perception task in both the hands-far control condition, $t(45) = -3.98$, $p < .001$, and the hands-near power-grasp condition, $t(45) = -2.691$, $p = .010$ (all other pairwise comparisons, n.s.). As can be seen in Figure 3, the difference between performance in the motion-detection task and form-perception task was smaller when participants held their hands near the display in a power-grasp posture than when they kept their hands in their laps.

Experiment 2

Figure 4 displays the mean percentage of signal dots present at the motion-coherence and form-coherence thresholds, averaged across the final four blocks of the motion-detection and form-perception tasks, respectively, in the hands-near precision-grasp condition and the hands-far control condition in Experiment 2. I performed a 2 × 2 within-subjects ANOVA on these threshold data with factors of task (motion detection, form perception) and hand posture (hands-near precision grasp, hands-far control). As for Experiment 1, this analysis yielded a significant main effect of task, $F(1, 45) = 4.22$, $p = .046$, $\eta_p^2 = .09$, and a significant interaction between task and hand posture, $F(1, 45) = 7.73$, $p = .008$, $\eta_p^2 = .15$, yet no main effect of hand posture ($p > .70$). However, planned pairwise comparisons showed that in Experiment 2, when participants kept their hands near the display—this time in a precision-grasp posture—their performance on the motion-detection task actually suffered compared with the hands-far control condition, $t(45) = -2.24$, $p = .030$. In addition, when participants held their hands near the display in a precision-grasp posture, their performance on the motion-detection task was significantly worse than in the form-perception task, $t(45) = -3.22$, $p = .002$, which demonstrates that hand posture differentially influenced thresholds across the motion-detection and form-perception tasks (all other pairwise comparisons, n.s.).

Experiments 3a and 3b

Figure 5 displays the mean percentage of signal dots present at the motion-coherence and form-coherence thresholds, averaged across the final four blocks of the motion-detection and form-perception tasks, respectively, in the hands-near power-grasp condition and the hands-near precision-grasp condition in Experiment 3a. I performed a 2 × 2 within-subjects ANOVA on these threshold data with factors of task (motion detection, form perception) and hand posture (hands-near power grasp, hands-near precision grasp). This analysis revealed a significant interaction between task and posture, $F(1, 45) = 5.30$, $p = .026$, $\eta_p^2 = .11$. The main effects of task ($p > .06$) and hand posture ($p > .30$) were not significant. Planned pairwise comparisons confirmed that the significant interaction was driven by two components: (a) Participants' performance on the form-perception task was better in

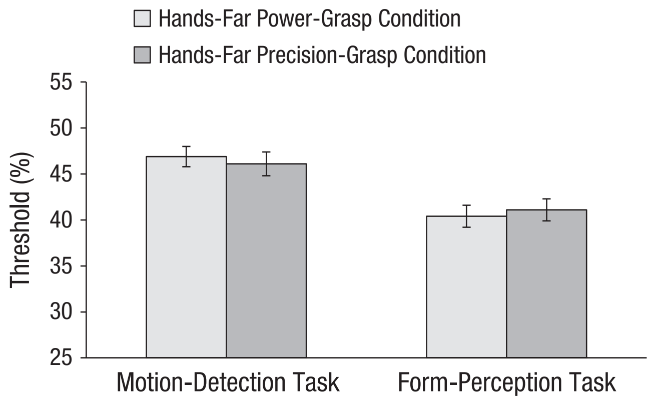

Fig. 6. Results from Experiment 3b: mean percentage of signal dots present at the motion-coherence threshold in the motion-detection task and at the form-coherence threshold in the form-perception task. The results are shown separately for the two hand-posture conditions. Error bars represent ±1 *SEM*.

the precision-grasp condition than in the power-grasp condition, $t(45) = 2.41$, $p = .020$, and (b) there was a significant cost to performance in the motion-detection task compared with the form-perception task in the precision-grasp condition, $t(45) = -2.56$, $p = .014$ (all other pairwise comparisons, n.s.).

Figure 6 displays the mean percentage of signal dots present at the motion-coherence and form-coherence thresholds, averaged across the final four blocks of the motion-detection and form-perception tasks, respectively, in the hands-far power-grasp condition and the hands-far precision-grasp condition in Experiment 3b. A 2 × 2 within-subjects ANOVA with factors of task (motion detection, form perception) and hand posture (hands-far power grasp, hands-far precision grasp) revealed no significant main effects or interaction (all *p*s > .17).

General Discussion

Across three experiments, I uncovered evidence that different postures—and presumably the actions these postures afford—differentially influence visual processing of stimuli near the hands. This work provides the first demonstration that, even in the absence of an explicit action plan or intention, the visual system biases processing toward information relevant to the actions people are currently prepared to take. The results of Experiment 1 are consistent with findings that suggest viewing information near hands positioned to afford a power grasp biases visual processing toward increased contribution from the high-temporal-resolution M pathway at the expense of the high-spatial-resolution P pathway (Abrams & Weidler, 2014; Goodhew et al., 2013; Gozli et al., 2012; Kelly & Brockmole, 2014): Participants showed superior motion detection and inferior form perception when their hands were positioned near the display in a power-grasp posture compared with a hands-far control condition.

However, in Experiment 2, when participants held their hands near the display in the precision-grasp posture, they were less sensitive to information necessary to make motion judgments but better able to distinguish form percepts than they were in the hands-far control condition. Positioning the hands to afford a detail-oriented precision grasp apparently reversed the bias associated with the power-grasp posture, which is consistent with the notion that precision-grasp postures may lead to increased contribution from the P pathway at the expense of the M pathway. Experiments 3a and 3b provide converging evidence for this differential biasing of visual processing tied to action affordances: When visual information was presented in peripersonal space, grasp posture influenced biases, yet when the same visual information appeared outside of the hands' grasping space, posture had no influence on processing—which is consistent with an action-specific account. Taken together, these results suggest that people are more sensitive to temporal visual information that will help them catch a ball when their hands are ready to make a power grasp, but show increased sensitivity to fine spatial detail when their hands are prepared to thread a needle with a precision grasp.[3]

The results of these experiments are consistent with an account of altered vision near the hands in which grasp posture introduces biases toward increased contribution from the M or the P pathway (e.g., Gozli et al., 2012). However, they are also compatible with other mechanisms proposed to explain near-hand effects. Bimodal visual-tactile neurons may strengthen representation of objects near the hands, creating an attentional bias for near-hand space (Reed et al., 2006, 2010). Bimodal neurons are selective for the size of observed objects and the grasps they afford (e.g., Fadiga, Fogassi, Gallese, & Rizzolatti, 2000). Representations from bimodal neurons tied to specific grasp affordances could have contributed to the different visual biases I observed. Another recent proposal explaining altered vision near the hands suggests that the hands influence the allocation of spatial attention, with a single hand in the power-grasp posture biasing toward a narrow focus of attention and two hands in this posture biasing toward a broader attentional focus (Bush & Vecera, 2014).

The hands' grasp posture could likewise influence the spatial scale of attention: Precision grasps may encourage a tight focus of attention that is beneficial to spatial sensitivity, whereas power grasps may instead facilitate a broadening of focus that is favorable to temporal sensitivity. In addition, greater biasing of contributions from the M or P pathway may in turn lead to enhancement of dorsal- or ventral-stream operations, respectively (Davoli, Brockmole, & Goujon, 2012; Tseng & Bridgeman, 2011). It is also important not to discount the potential importance of top-down contributions, such as instructional set, to vision near the hands (Garza, Strom, Wright, Roberts, & Reed, 2013; Reed, Leland, Brekke, & Hartley, 2013): Participants in the current experiment received no instructions about the relevance of their hand positions, but the emphasis on correct hand placement at the start of each block presumably drew their attention to the hands' posture, potentially enhancing their impression of the importance of hand position to task performance.

Although the mechanisms driving alterations in visual processing near the hands warrant further investigation, the results of the current study point to the important roles of grasp posture and action affordances in vision. Future studies exploring vision near the hands may benefit from additional manipulations to help further characterize the visual biases associated with different postures and the actions observers are prepared to take. In addition, although initial studies investigating vision near hands in the power-grasp posture suggest that the hands need not be visible in order for such biases to occur (Abrams et al., 2008; Reed et al., 2006), future work might also examine whether the influence of the precision-grasp posture likewise does not rely on the hands' visibility. Nevertheless, the current results clearly illustrate the importance of bodily context in vision: Visual processing is embodied, and it changes not just as a result of the potential for *any* action but adjusts specifically for *particular types* of actions. People's ability to see the world around them is tied to adaptations that allow for effective action in the environment.

Author Contributions

L. E. Thomas is the sole author of this article and is responsible for its content.

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Declaration of Conflicting Interests

The author declared that she had no conflicts of interest with respect to her authorship or the publication of this article.

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Notes

1. Near-hand effects on vision are sensitive to the number of hand postures tested within a single experiment. The most effective investigations pit two postures against each other at a time (Schultheis & Carlson, 2013).

2. To ensure adequate power in investigating a new effect, I chose a sample size roughly double those used in previous research on near-hand effects (e.g., Abrams et al., 2008). Data collection stopped after 46 participants were tested.

3. Participants' relatively weaker performance on the motion-detection task than on the form-perception task across Experiments 1 and 2 suggests an alternative explanation for the results: Power-grasp postures may benefit tasks in which observers show low sensitivity, whereas precision-grasp postures may benefit tasks to which observers are more sensitive. However, a subset of participants showing minimal performance differences across the motion-detection and form-perception tasks showed a pattern of results that was not significantly different from that of the full data set, which supports the idea that the effect of grasp posture is a function of task type rather than task sensitivity.

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