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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 that may assist them in evaluating items that are candidates for action. I investigated the hypothesis that hand postures affording 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 task, the precision grasp posture instead facilitated performance on the form task. These results suggest that the visual system weights processing based on an observer's current affordances for specific actions: fast and forceful power grasps enhance temporal sensitivity, while detail-oriented precision grasps enhance spatial sensitivity.

Keywords

Embodied perception; visual processing

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 objects outside of their reach. Observers experience changes in visual processing near their hands including alterations in perception (Cosman & Vecera, 2010), attention (e.g., Abrams et al., 2008; Reed et al., 2006), and memory (Thomas et al., 2013; Tseng & Bridgeman, 2011) (see Brockmole et al., 2013 and Tseng et al., 2012 for reviews). 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 visual processing near the hands occur specifically within the hands' grasping space (Reed et al., 2010) and drop off as the distance between the hands and a visual stimulus increases (Tseng & Bridgeman, 2011). These nearby-hand influences on vision may therefore reflect an adaptive sensitivity of the visual system to behavioral contexts (e.g., Brockmole et al., 2013; Graziano & Cooke, 2006).

While investigations of altered vision near the hands appeal to action-based explanations for why these changes occur, the question of how the hands' potential to engage in specific actions may mediate visual processing biases remains relatively unexplored. Although most

of the literature on nearby-hand effects focuses on how the presence of the hands, *in general*, influences visual processing, researchers have investigated a limited range of hand postures and action affordances. Typically, observers' performance on a visual task under a hands-near condition is compared against 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 (Figure 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 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 when compared to hands-far conditions—evidence that suggests information processing near hands positioned for a power grasp may be biased toward increased contributions from the magnocellular (M) visual pathway, while processing away from the hands may reflect stronger contributions from the parvocellular (P) pathway (e.g., Abrams & Weidler, 2014; Goodhew et al., 2013; Gozli et al., 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 versus another have the potential to shape the way we 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. We 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). While a precision grasp posture (Figure 1B) affords actions that bring objects into contact with areas of the hand with high tactile spatial acuity that aid in delicate and detail-oriented work (e.g., threading a needle), a power grasp posture instead affords actions that bring objects into contact with lower sensitivity areas of the hand that enable a more forceful grip (Craig, 1999; Craig & Lyle, 2001; Johansson & Valbo, 1979). Observers represent objects based on 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 et al., 2008). I hypothesize that the visual system will likewise distinguish between power-versus-precision grasp postures in nearby-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 while observers are facilitated in rapidly detecting targets appearing near a hand positioned to afford a power grasp (e.g., Reed et al., 2006; 2010), 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 near hands 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—while a precision grasp posture may 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 have been linked to M and P pathway function respectively (e.g., McKendrick et al., 2005). In each experiment, participants performed these tasks under two different hand posture conditions: hands-near power grasp versus hands-far control (Exp. 1), hands-near precision grasp versus hands-far control (Exp. 2), hands-near power grasp versus hands-near precision grasp (Exp. 3a), and hands-far power grasp versus hands-far precision grasp (Exp. 3b)¹. While positioning the hands near the display in a power grasp posture enhanced motion detection, 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 based on an observer's current affordances for specific actions.

Method

Overview of tasks

All participants performed both a global motion detection and global form perception task (modified from McKendrick et al., 2005). Tasks were presented on a monitor set to a resolution of 1024x768 pixels at a refresh rate of 60Hz. Participants performed both tasks while stabilized on a chinrest positioned 36cm from the display. For each task, participants viewed an array of 100 one-pixel black dots presented in a 150x150 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 in which each frame appeared for 50ms for a total of 400ms viewing time per trial. On each frame transition, a portion of signal dots shifted one pixel in the signal direction, randomly determined on each sequence to move directly left or right. The remaining portion of noise dots shifted the same distance in random directions. To minimize local motion cues, individual dot locations were randomly determined every two frames, preventing 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 make a verbal response indicating whether the primary global motion was to the left or right. An experimenter sitting next to the participant but unable to see the display entered these responses on a keyboard. I used a staircase procedure to determine individual participants' motion thresholds. Initially, 80% of the dots in the display moved in the signal direction.

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

The percentage of signal dots was decreased by 8% for 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%. 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 would decrease by 8% following three correct responses and increase by 8% following a single incorrect response. After the third reversal, the percentage of signal dots would decrease by 4% following three correct responses and increase by 4% following an incorrect response. Following the fifth reversal, the percentage of signal dots would decrease or increase by 2% based on the same rules. A block of motion sequence trials would terminate 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 400ms. 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 (Figure 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.

Following each presentation, participants made a verbal response indicating whether they experienced a radial or concentric global precept and an experimenter entered this response with a keyboard. I determined form perception thresholds using the same modified three-down, one-up staircase procedure employed for the global motion task.

Experiment 1—Forty-six volunteers² from the NDSU Psychology Department participant pool participated for course credit. All participants had normal or corrected-to-normal vision. Participants in the first experiment performed the motion and form tasks under two different hand postures: the standard hands-near power grasp posture (Figure 1A) and a hands-far control posture (Figure 1C). In the power grasp posture, participants grasped the display between both hands, placing the base of their thumbs over tape indicators on either side of the display to ensure similar positioning across participants and curling their fingers around the back of the display, bringing the palm 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 8 blocks of the motion and 8 blocks of the form task in a counterbalanced order. 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.

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

Experiment 2—An additional 46 volunteers from the NDSU participant pool with normal or corrected-to-normal vision who did not take part in the previous experiment participated in Experiment 2 for course credit. The procedure of Experiment 2 was identical to Experiment 1 with the following exception: instead of employing a hands-near posture in which participants adopted a stance affording a power grasp that brought the display into contact with the palms of the hands, participants instead engaged in a hands-near posture that afforded a precision grasp (Figure 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, preventing them from making contact with the display edges at any location other than at the thumbs and forefingers. In addition to performing the motion and form tasks under this precision grasp posture, participants also performed half of all blocks under the same hands-far control posture employed in Experiment 1.

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

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

Results

Experiment 1

Figure 3 displays the mean percentage of signal dots at threshold averaged across the final four blocks of the motion and form tasks under both the hands-near power grasp and hands-far control conditions in Experiment 1. I submitted participants’ thresholds under the different conditions to a 2x2 within-subjects ANOVA with factors of task type (motion detection/form perception) and hand posture (hands-near power grasp/hands-far control). This analysis revealed a main effect of task ($F(1,45)=12.71$, $p=0.001$, partial $\eta^2=0.22$) as well as a significant interaction between task and hand posture ($F(1,45)=7.00$, $p=0.016$, partial $\eta^2=0.12$). The main effect of hand posture was not significant ($p>0.50$). Planned pairwise comparisons confirmed that hand posture differentially influenced performance on the form and motion tasks: participants tended to have lower thresholds in the form task (i.e., were able to distinguish between radial and concentric patterns with a smaller percentage of signal dots) 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 task was worse than performance on the form task both under the hands-far control condition ($t(45)=-3.98$, $p<0.001$) and the hands-near power grasp posture ($t(45)=-2.691$, $p=0.010$) (all other pairwise comparisons *n.s.*). As can be seen in Figure 3, the motion task was less detrimental 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 thresholds for the motion and form tasks under both the hands-near precision grasp and hands-far control conditions in Experiment 2. I performed a 2x2 within-subjects ANOVA on these threshold data with factors of task (motion/form) and hand posture (hands-near precision grasp/hands-far control). Similarly to the results of Experiment 1, this analysis yielded a significant main effect of task ($F(1, 45)=4.22$, $p=0.046$, partial $\eta^2=0.09$) and a significant interaction between task and hand posture ($F(1,45)=7.73$, $p=0.008$, partial $\eta^2=0.15$), yet no main effect of stance ($p>0.70$). 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 task actually suffered compared to the hands-far control condition ($t(45)=-2.24$, $p=0.030$). In addition, when participants held their hands near the display in a precision grasp posture, their performance on the motion task was significantly worse than in the form task ($t(45)=-3.22$, $p=0.002$), demonstrating that hand posture differentially influenced thresholds across the motion and form tasks (all other pairwise comparisons *n.s.*).

Experiment 3

Figure 5 displays the mean thresholds for the motion and form tasks under both the hands-near power grasp and hands-near precision grasp postures in Experiment 3a. Participants' thresholds on these tasks were analyzed in a 2x2 within-subjects ANOVA with factors of task (motion/form) and hand posture (hands-near power grasp/hands-near precision grasp). This analysis revealed a significant interaction between task and posture ($F(1, 45)=5.30$, $p=0.026$, partial $\eta^2=0.11$). The main effects of task ($p>0.06$) and hand posture ($p>0.30$) were not significant. Planned pairwise comparisons confirmed that the significant interaction was driven by participants' superior performance on the form task under the precision grasp posture when compared with the power grasp posture ($t(45)=2.41$, $p=0.020$) and a significant cost to performance in the motion task compared to the form task under the precision grasp posture ($t(45)=-2.56$, $p=0.014$) (all other pairwise comparisons *n.s.*).

Figure 6 displays the mean thresholds for the motion and form tasks under the hands-far power grasp and hands-far precision grasp postures in Experiment 3b. A 2x2 within-subjects ANOVA with factors of task (motion/form) and hand posture (hands-far power grasp/hands-far precision grasp) revealed no significant main effects or interaction (all p -values >0.17).

General Discussion

Across three experiments, I have uncovered evidence that different postures—and presumably the actions these postures afford—differentially influence visual processing 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 we 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 to a hands-far control condition. Yet in Experiment 2, when participants held their hands equally near the display, but did so in a precision grasp posture, they were actually less sensitive to information necessary to make motion judgments but better able to distinguish form precepts 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, consistent with the notion that precision grasp postures may lead to increased contribution from the P pathway at the expense of the M pathway. Experiment 3 provides 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—consistent with an action-specific account—when the same visual information appeared outside of the hands' grasping space, posture had no influence on processing. Taken together, these results suggest 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 grasp³.

Although the results of these experiments are consistent with an account of altered vision near the hands based on grasp posture-based biases in processing along the M versus P pathways (e.g., Gozli et al., 2012), they are also compatible with other mechanisms proposed to explain nearby-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 to the size of observed objects and the grasps they afford (e.g., Fadiga et al., 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 beneficial to spatial sensitivity while power grasps may instead facilitate a broadening of focus amenable to temporal sensitivity. In addition, a differential biasing of contributions from the M and P pathways may in turn lead to enhancement of dorsal versus ventral stream operations (Davoli et al., 2012; Tseng & Bridgeman, 2011). It is also important not to discount the potential importance of top-down contributions such as

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

instructional set to vision near the hands (Garza et al., 2013; Reed et al., 2013): participants in the current experiment received no instruction about the relevance of their hand position, but the emphasis on correct hand placement at the start of each block presumably drew attention to the hands' posture, potentially enhancing participants' impression of the importance of hand position to task performance.

While the mechanisms driving alterations in visual processing near the hands warrant further investigation, the results of the current study point to the important role grasp posture and action affordances play in vision. Future work 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 suggests that the hands need not be visible in order for biases to occur (Abrams et al., 2008; Reed et al., 2006), future work may also seek to examine whether the influence of grasp posture likewise does not rely upon the hands' visibility. Nevertheless, the current results clearly illustrate the importance of bodily context in vision: visual processing is embodied, changing not just as a result of the potential for *any* action, but adjusting specifically for *particular types* of actions. Our ability to see the world around us is tied to adaptations that allow for effective action in the environment.

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Figure 1.
Hand position in (a) the power grasp posture, (b) the precision grasp posture, and (c) the hands-far posture.

Figure 2.
Example form perception stimuli (a) 80% radial signal dots (b) 40% concentric signal dots.

Figure 3. Mean percentage of signal dots at threshold for Experiment 1. Error bars represent ± 1 s.e.m.

Figure 4. Mean percentage of signal dots at threshold for Experiment 2. Error bars represent ± 1 s.e.m.

Figure 5. Mean percentage of signal dots at threshold for Experiment 3a. Error bars represent ± 1 s.e.m.

Figure 6. Mean percentage of signal dots at threshold for Experiment 3b. Error bars represent ± 1 s.e.m.