Consciousness and Cognition 64 (2018) 50–60

Contents lists available at ScienceDirect

Consciousness and Cognition

journal homepage: www.elsevier.com/locate/concog

Immobilization does not disrupt near-hand attentional biases

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ARTICLE INFO

Keywords:
Action
Visual attention
Affordance
Grasping
Peripersonal space
Proximity

ABSTRACT

Observers show biases in attention when viewing objects within versus outside of their hands' grasping space. While the hands' proximity to stimuli plays a key role in these effects, recent evidence suggests an observer's affordances for grasping actions also shape visual processing near the hands. The current study examined the relative contributions of proximity and affordances in introducing attentional biases in peripersonal space. Participants placed a single hand on a visual display and detected targets appearing near or far from the hand. Across conditions, the hand was either free, creating an affordance for a grasping action, or immobilized using an orthosis, interfering with the potential to grasp. Replicating previous findings, participants detected targets appearing near the hand more quickly than targets appearing far from the hand. Immobilizing the hands did not disrupt this effect, suggesting that proximity alone is sufficient to facilitate target detection in peripersonal space.

Bruce Bridgeman was an early contributor to a growing body of research which has provided strong evidence that the hands' proximity to visual information can affect performance on many types of visual tasks, including target detection (Reed, Grubb, & Steele, 2006), visual search (Abrams, Davoli, Du, Knapp, & Paull, 2008), and change detection (Tseng & Bridgeman, 2011). These visual changes in peripersonal space may be the result of an attentional prioritization driven by signals from bimodal visuotactile neurons (Reed et al., 2006) or a bias toward information carried via the action-oriented magnocellular pathway at the expense of the detail-oriented parvocellular pathway (e.g., Gozli, West, & Pratt, 2012). Recent hybrid accounts of altered vision near the hands suggest that attention may drive changes in the balance between signals originating from the magnocellular versus parvocellular visual pathways (Caplette, Wicker, Gosselin, & West, 2017; Goodhew & Clarke, 2016). Although the mechanisms behind visual biases in peripersonal space remain under debate in the literature, virtually all work on altered vision near the hands suggests processing changes reflect the visual system's prioritization of information that is relevant to immediate physical interaction (e.g., Brockmole, Davoli, Abrams, & Witt, 2013). Recent work supports this notion, demonstrating that an observer's ability to interact with the environment, via manipulations in hand position or posture, can modulate visual biases near the hands (Bush & Vecera, 2014; Reed, Betz, Garza, & Roberts, 2010; Thomas, 2013, 2015, 2017). Although the hands' proximity to stimuli by definition plays a necessary role in altered vision near the hands, the importance of the hands' readiness for action is less clear. Are grasp affordances—the hands' ability to interact with the environment—a driving mechanism in near-hand effects, or is the hands' proximity to visual information in the absence of affordances sufficient to elicit processing changes?

Early research on visual biases in peripersonal space focused on proximity manipulations, comparing visual task performance under hands-near and hands-far conditions. An initial study found participants are faster to detect targets appearing near a single hand placed on one side of a display than to detect targets appearing on the opposite side of the display (Reed et al., 2006). Another early investigation of altered vision near the hands focused on a manipulation in which observers take hold of a display with both hands or rest their hands below the display, finding evidence for delayed attentional disengagement near the hands (Abrams et al.,

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https://doi.org/10.1016/j.concog.2018.05.001
Received 30 January 2018; Received in revised form 30 April 2018; Accepted 3 May 2018

2008). Additional work demonstrated that nearby-hand effects are not reliant on the hands serving as a visual anchor (e.g., Cosman & Vecera, 2010), nor are they a result of atypical body positioning with respect to visual displays (Davoli, Feng, Montana, Garverick, & Abrams, 2010). However, the biases associated with viewing information in peripersonal space diminish as the distance between the hand(s) and the relevant stimuli increases (Adam, Bovend'Eerdt, van Dooren, Fischer, & Pratt, 2012; Tseng & Bridgeman, 2011), suggesting that altered performance in hands-near conditions is a direct result of stimuli appearing in close proximity to the hands—that is, within the hands' grasping space.

Although it is clear that the hands' proximity to visual stimuli plays a role in how observers process these stimuli, recent research suggests proximity may be necessary, but not sufficient, for altered vision in peripersonal space. Instead, action affordances may also drive these effects. Action affordances have been operationalized in various ways (e.g., Gibson, 1979; Norman, 1988; Thill, Caligiore, Borghi, Ziemke, & Baldassarre, 2013), but here, we use the term to denote an observer's perceivable ability to interact with the immediate environment. According to this approach, representations of visual information incorporate a perceiver's current motor capacities (e.g., Tucker & Ellis, 2001). An affordance account of visual biases in peripersonal space suggests that the hands' capabilities to grasp nearby stimuli will shape processing of these stimuli.

Several studies support the potential importance of grasp affordances in near-hand effects. Initial evidence favoring this interpretation came from work investigating near-hand facilitation in a simple target detection task. While observers are faster to detect a target appearing near an open palm propped against one side of a display than targets appearing on the other side of the display (Reed et al., 2006), there is no proximity advantage for targets appearing equally near the back of the hand or forearm (Reed et al., 2010). In this paradigm, facilitation occurs exclusively when targets appear within the hands' grasping space—that is, when there is an affordance for a grasping action. Interestingly, this near-hand facilitation is limited not only to targets appearing within the hands' grasping space, but also by the particular *type* of grasp the hands are ready to perform (Thomas, 2013). When a hand is positioned to afford a power grasp—with fingers held together so they may function as a unit to secure an item against the palm—near-hand facilitation occurs. However, when a hand is instead positioned to afford a precision grasp—with thumb and forefinger near each other in a pinching posture—a target's proximity to the hand has no impact on detection times (Thomas, 2013). This result hints at the importance—and specificity—of grasp affordances in shaping visual biases in peripersonal space.

Additional studies examining near-hand effects associated with power versus precision grasp affordances suggest that visual biases are specific to the type of actions observers are prepared to take (Thomas, 2015, 2017). In these experiments, participants adopting a power grasp posture with both hands on either side of a display showed increased sensitivity on a temporal visual processing task, indicating preferential processing of information that is most relevant to completing fast and forceful power grasp actions. However, participants who instead adopted a precision grasp posture showed enhanced sensitivity to fine spatial detail, suggesting the visual system emphasized processing of information that aids in delicate precision grasp actions. These findings highlight the potential relevance of grasp affordances to visual processing in peripersonal space, suggesting that visual biases are specifically tied to adaptations that promote effective action (Thomas, 2015).

Although this recent work examining the manner in which power versus precision grasp affordances can shape near-hand effects suggests considerations of proximity may be subsumed under action affordances when conceptualizing the boundary conditions for altered vision near the hands, not all evidence aligns with this claim. Several experiments have demonstrated visual biases associated with observers positioning a hand palm-down below a display (Adam et al., 2012; Lloyd, Azanon, & Poliakoff, 2010; Tseng & Bridgeman, 2011)—a posture that is not necessarily compatible with a ready affordance for grasping visual stimuli. In addition, near-hand effects occur when observers hold their hands near either side of a display that is shielded by a cardboard wall blocking the hands' visibility and, potentially, preventing grasping actions toward the display (Abrams et al., 2008).

While recent research suggests action affordances play a role in visual processing biases in near-hand space, it remains unclear whether observers experience altered vision near their hands in the absence of grasp affordances. To investigate this issue, it is important to find a method that isolates proximity manipulations from action affordances. Behavioral (e.g., Ambrosini, Sinigaglia, & Costantini, 2012; Moreau, 2013) and neural (Kühn, Werner, Lindenberger, & Verrel, 2014) evidence suggests that movement restraint (i.e., immobilization) produces near-instantaneous changes in the representation of affordances. For example, when right-handed observers passively view graspable objects with handles oriented to the left, they show greater right dorsal premotor cortex activation when the dominant hand is immobilized with an orthosis—a brace that prevents the fingers, hand, and wrist from moving—than when this hand is unrestrained. This result suggests that restraining the dominant hand introduces changes in premotor processing that disrupt the right hand's typical grasping affordances, thereby boosting affordances for the non-dominant left hand (Kühn et al., 2014). In order words, mere knowledge of the inability to move the hand—in the absence of extensive experience with immobilization—can alter neural representation of affordances. Immobilization therefore is a promising method for examining how proximity, in the absence of a strong affordance for grasping action, contributes to visual biases near the hands.

In our attempt to tease apart the influence of hand proximity and grasp affordances to altered vision near the hands, we focused specifically on the seminal near-hand target detection paradigm in which observers show a general attentional prioritization to the space near a single hand (e.g., Reed et al., 2006). While recent findings raise questions about the replicability and generalizability of near-hand effects in visual search and change detection paradigms (Andringa, Boot, Roque, & Ponnaluri, 2018), the simple detection task is well established in the literature for eliciting near-hand facilitation, yielding multiple replications (e.g., Reed et al., 2010; Sun & Thomas, 2013), and has previously shown sensitivity to power versus precision grasp affordance manipulations (Thomas, 2013). We varied proximity by asking participants to either place a single hand so the open palm faced the edge of the display or to place this hand in their laps. Across certain conditions, participants wore an orthosis that immobilized the fingers and wrist, disrupting grasp affordances while still allowing participants to place a hand proximal to the display in an open palm/power grasp posture. If proximity is sufficient to introduce visual biases near the hands, we should find similar patterns of facilitation in detecting targets