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Immobilization does not disrupt near-hand attentional biases

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A R T I C L E I N F O

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A B S T R A C T

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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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

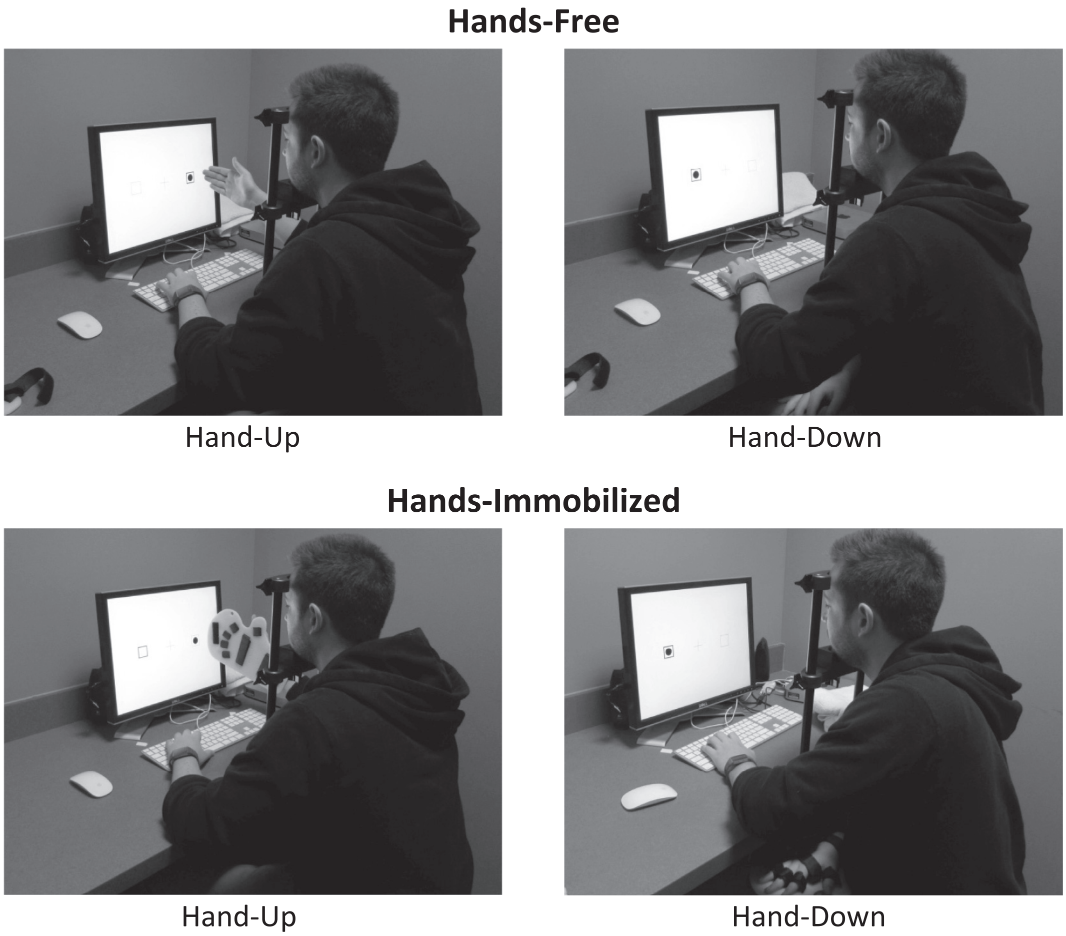

Fig. 1. Experimental conditions for experiment 1. A hand was either held next to the target box, or down in the lap. One group of participants completed the task with their hands unrestrained and free to move, while the other group completed the task wearing the orthosis.

near the hands regardless of whether the hands are free or immobilized. However, if grasp affordances are a necessary driver of altered vision near the hands, then immobilizing the hands—disrupting an affordance for grasping—should eliminate near-hand facilitation. Finally, proximity and affordance may make separate contributions to a pattern of altered vision near the hands, in which case we may expect to see weaker facilitation or a qualitatively different pattern of facilitation when the hands are immobilized than when they are free.

1. Experiment 1

In Experiment 1, we examined the role hand proximity and grasp affordances play in visual biases near the hands using a between-subjects design. All participants completed the target detection task under conditions in which they placed a single open-palmed hand near one of two potential target locations on the display as well as under baseline conditions in which they kept their non-responding hand in their lap (see Fig. 1). One group of participants performed this task while their non-responding hand was unrestrained, while the second group of participants strapped an orthosis to their non-responding hand, disrupting the hand's affordance for grasping.

2. Method

2.1. Participants

130 undergraduate volunteers from the North Dakota State University participant pool—100 of whom ultimately contributed data to analyses—participated in the study for course credit or a small monetary compensation. All participants had normal or corrected-to-normal vision and self-reported as right-handed.

2.2. Stimuli and apparatus

All participants performed a Posner cueing task (Posner, Walker, Friedrich, & Rafal, 1987) with variable hand positions. Stimuli were presented on a monitor with a resolution of 1024 × 768 pixels and a refresh rate of 60 Hz. Viewing distance was fixed at 45 cm from the monitor using a chinrest. Stimuli consisted of a black central fixation cross and two empty black squares measuring 3.25° positioned 7.09° to the left and right of fixation. The target stimulus was a black dot (2.44°).

2.3. Procedure and design

Each trial of the cuing task began with a random delay between 1500 and 3000 ms in which the fixation cross and squares were displayed. Following the delay, the outline of one of the two squares darkened, serving as a cue to the likely location of the target. Two hundred milliseconds after cue onset, a target dot appeared in the cued location (70% of trials), the uncued location (20% of trials), or did not appear (10% of trials). Participants were instructed to press the 'h' key as soon as a target appeared. Each block contained 56 valid trials, 16 invalid trials, and 8 catch trials for a total of 80 trials per block. Trial type was randomized within blocks. Participants were first familiarized with the cueing task during a short 20 trial practice block in which they responded with their dominant hand and kept their non-dominant hand in their lap. They then performed eight blocks of trials in which hand proximity was manipulated across blocks. Before each block began, participants received instructions on hand placement detailing one of four possible configurations: (1) respond with the left hand and keep the right hand in the lap, (2) respond with the left hand and hold the right hand next to the display, (3) respond with the right hand and keep the left hand in the lap, and (4) respond with the right hand and hold the left hand next to the display. Instructions were given verbally and provided in writing on the computer display. For blocks in which participants held a hand near the display, they were instructed to place their hand with the palm facing inward (see Fig. 1). To ensure reliable hand placement across participants, three black dots were shown between the left or right square and the edge of the display along with the written instructions. These guide dots disappeared when participants began the first trial in a block. An experimenter monitored participants for compliance with the hand placement instructions throughout the experiment. Participants ran through two blocks of each of the four configurations in a randomized order.

Previous research has suggested that near-hand effects on vision are sensitive to the number of hand postures tested within a single experiment and that the most effective investigations pit only two postures against each other at a time (e.g., hands-up versus hands-down) (Schultheis & Carlson, 2013). We therefore elected to introduce differences in action affordance as a between-subjects variable rather than have participants complete trials in three different hand posture conditions (i.e., down, free, and immobilized). Participants in the *hands-free condition* (n = 63) completed the task with both hands free and unrestrained, whereas participants in the *hands-immobilized condition* (n = 67) completed the task with an orthosis restraining their non-responding hand. Participants in both groups placed their hands in the same locations, but participants in the hands immobilized group wore a large, mitten-shaped, rigid orthosis. This orthosis was secured firmly to the non-responding hand with individual Velcro straps around the base of each finger and thumb, and additional straps around the back of the hand and wrist (see Fig. 1). The orthosis prevented participants in the immobilized condition from curling their fingers or moving their wrist, presumably interfering with representations of a grasping affordance toward the display. Similar devices have been shown to alter representations of grasp affordances (Kühn et al., 2014).

3. Results and discussion

Seven participants in the hands-free condition and 13 participants in the hands-immobilized condition made response errors on more than 50% of catch trials, indicating a lack of engagement with the cueing task. These participants were dropped from the study. Another six participants in the hands-free condition and four participants in the hands-immobilized condition were dropped from the study for failing to consistently follow hand placement instructions, leaving a total of 50 participants remaining in each condition. To eliminate anticipation and inattention errors, trials with a reaction time of less than 200 ms or greater than 1000 ms were excluded from analyses.[1] For the remaining 100 participants, a total of 10.79% of trials with excessively long or short reaction times were omitted from analyses.

Figs. 2 and 3 display participants' mean reaction times to detect a target across conditions. These data were submitted to a 2 × 2 × 2 × 2 mixed ANOVA, the results of which are displayed in Table 1. Within-subjects factors included hand position (up versus down), target distance (near versus far from the hands) and cue validity (valid versus invalid trials), while affordance (free versus immobilized) was analyzed as a between-subjects factor. We defined target distance based upon whether the target appeared on the same side of the display as the responding hand (far, e.g., right side target for blocks in which participants responded with the right hand) or on the side of the display with the non-responding hand (near, e.g., left side target for blocks in which participants responded with the right hand), regardless of whether the non-responding hand was up or down. Although previous research on near-hand facilitation has found reaction time advantages for both validly and invalidly cued targets presented near a hand and presented data collapsed across this factor (e.g., Reed et al., 2010; Thomas, 2013), facilitation can potentially manifest either as a general prioritization of space near the hand or via an influence on the *shifting* of attention. In the former case, we expect to see near-hand reaction time advantages for valid and invalid cue trials. However, if proximity affects the shifting of attention, increasing the salience of near-hand cues, we expect to see a relative RT disadvantage specifically for invalidly cued targets appearing away from the

[1] These criteria for eliminating trials based on reaction time measures are taken directly from Reed et al. (2006).

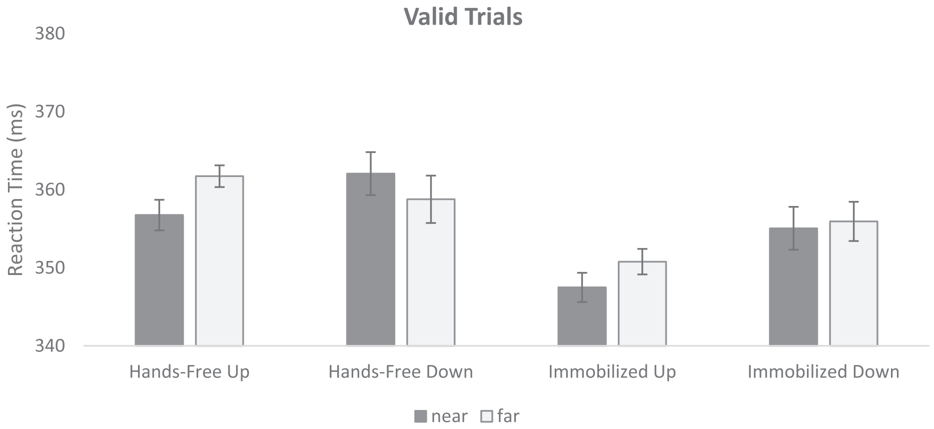

Fig. 2. Results from Experiment 1 for valid trials: mean reaction time comparisons of target near to target far for each hand condition. Error bars represent ± 1 SEM.

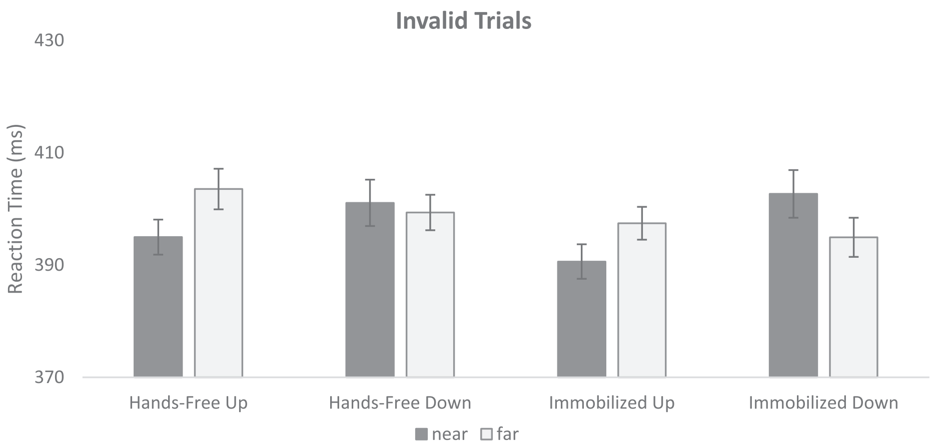

Fig. 3. Results from Experiment 1 invalid trials: mean reaction time comparisons of target near to target far for each hand condition. Error bars represent ± 1 SEM.

Table 1
Analysis of variance results for Experiment 1.

Factor	*F*	*p*	η_p^2
Hand position	*F*(1,98) = 1.674	.199	.017
Target distance	*F*(1,98) = 1.208	.275	.012
Validity	F(1,98) = 359.464	< .001	.786
Affordance	F(1,98) = .122	.728	.001
Hand position * affordance	*F*(1,98) = 2.243	.137	.022
Target distance * affordance	*F*(1,98) = .196	.659	.002
Validity * affordance	*F*(1,98) = 1.157	.285	.012
Hand position * target distance	*F*(1,98) = 8.836	.004	.083
Hand position * target Distance * affordance	*F*(1,98) = .001	.976	.000
Hand position * validity	*F*(1,98) = .053	.818	.001
Hand position * validity * affordance	*F*(1,98) = .030	.862	.000
Target distance * validity	*F*(1,98) = .039	.845	.000
Target distance * validity * affordance	*F*(1,98) = 1.071	.303	.011
Hand position * target Distance * validity	*F*(1,98) = 1.341	.250	.014
Hand position * target Distance * validity * affordance	*F*(1,98) = 1.980	.163	.020

hand (Reed et al., 2006). To explore the possibility that affordance and proximity may exert separate influences on near-hand facilitation in this manner, we therefore report all analyses with the factor of validity included.

As can be seen in Table 1, the ANOVA yielded a significant main effect of validity ($F(1,98) = 359.46$, $p < .001$, partial eta squared = .786), as well as a significant interaction between hand position and target distance ($F(1,98) = 8.84$, $p = .004$, partial eta squared = .083) reflecting a reaction time advantage in detecting near targets in the hands-up conditions. No other main effects or interactions approached significance. Importantly, the factor of affordance did not interact with any other factors in the design.

Replicating previous findings (e.g., Reed et al., 2006), we found a significant interaction between hand position and target distance, providing additional support for the claim that observers experience facilitation in detecting targets that appear near the palm of the hand. However, we found no evidence to suggest that this near-hand facilitation differed for participants across the hands-free and hands-immobilized groups, nor did it vary as a function of cue validity, as the affordance manipulation yielded neither a significant main effect nor did it interact with any other factors. The results of Experiment 1 suggest that, at least in the case of target detection near the palm, proximity alone may be sufficient to obtain near-hand facilitation.

4. Experiment 2

The results of our first experiment are consistent with the interpretation that immobilization does not disrupt attentional prioritization in near-hand space. However, before embracing a single null result, we wished to replicate this finding in a new sample of participants. In Experiment 2, we employed a within-subjects design in order to facilitate direct comparisons between hands-free and hands-immobilized conditions. By having each participant experience both the free and immobilized conditions, we reasoned that the overall salience of the orthosis—and its implications for reduced grasping affordances—might be emphasized.

5. Method

5.1. Participants

Another 61 undergraduate volunteers from the North Dakota State University participant pool, none of who had participated in Experiment 1 and 51 of who ultimately contributed data to analyses, ran in Experiment 2 for course credit. As with Experiment 1, all participants were right-handed and had normal or corrected-to-normal vision.

5.2. Stimuli, apparatus, procedure, and design

Experiment 2 was a within-subjects replication of Experiment 1 in which participants performed the same target detection task. In the interest of further investigating potential relationships between target distance, affordance, and cue validity, we asked a single group of participants to alternate between wearing and not wearing an orthosis to immobilize their hand. We tested four hand configurations: (1) respond with the right hand, keep the left hand next to the display without the orthosis, (2) respond with the right hand, keep the left hand next to the display with the orthosis on, (3) respond with the left hand, keep the right hand next to the display without the orthosis, and (4) respond with the left hand, keep the right hand next to the display with the orthosis on. Participants ran through each configuration twice in a randomized order, for a total of eight blocks.

6. Results and discussion

Four participants made response errors on more than 50% of catch trials and so were dropped from the study. Another six participants were dropped from the study for failing to consistently follow the hand placement instructions, leaving a total of 51 participants providing data for analysis. As in the previous analysis, trials with a reaction time of less than 200 ms or greater than 1000 ms were excluded. This omitted 9.04% of trials from analyses.

Figs. 4 and 5 display mean reaction times to detect targets across conditions. Reaction times were submitted to a 2 × 2 × 2

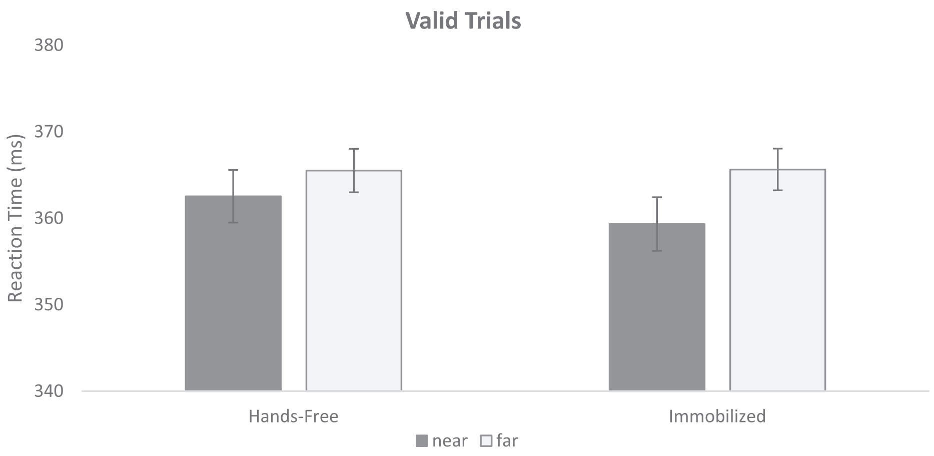

Fig. 4. Results from Experiment 2 valid trials: mean reaction time comparisons of target near to target far for Hands-free vs. Hands-Immobilized. Error bars represent ± 1 SEM.

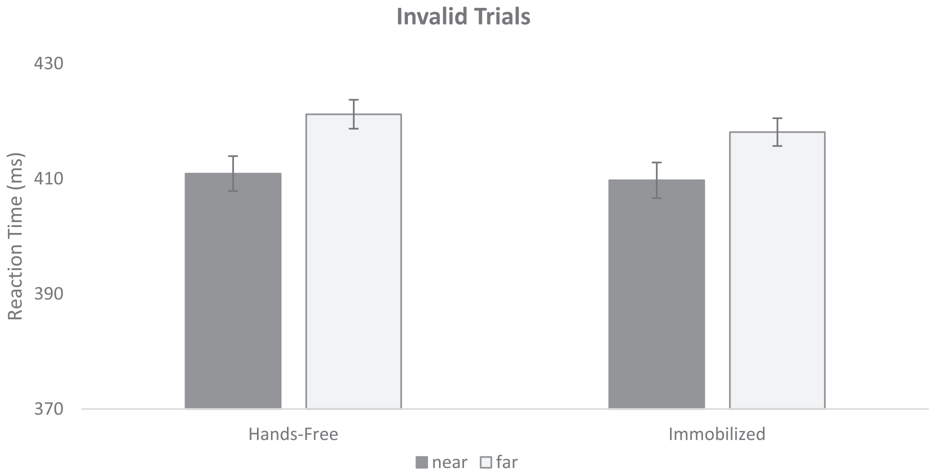

Fig. 5. Results from Experiment 2 invalid trials: mean reaction time comparisons of target near to target far for Hands-free vs. Hands-Immobilized. Error bars represent ± 1 SEM.

within-subjects ANOVA, with factors of target distance and validity (both unchanged from the previous experiment) and the now within-subjects factor of affordance (hands free vs. hands immobilized). The results of this analysis are shown in Table 2. Unsurprisingly, we again found a significant main effect of validity ($F(1,50) = 138.40$, $p < .001$, partial eta squared = .735). In addition, there was a significant main effect of target distance ($F(1,50) = 11.35$, $p = .001$, partial eta squared = .185). No other main effects or interactions were statistically significant, although there was a marginal interaction between validity and target distance (see Table 2). As can be seen in the figures, the main effect of target distance reflects participants' relative advantage in responding to targets appearing near the hand in both the free and immobilized conditions.

As was the case for participants in Experiment 1, participants in Experiment 2 were generally faster to detect targets appearing near their hands than targets appearing far from their hands regardless of whether the hand was at the ready to perform a grasping action or was instead restricted in its movement by an orthosis. This additional within-subjects examination of the relative contributions of proximity and grasp affordances to near-hand attentional prioritization provides converging evidence in support of the claim that physical grasp affordances are not essential for observes to experience facilitation in detecting targets appearing near the hand.

While the results of both Experiments 1 and 2 suggest that immobilization does not interfere with the hands' ability to introduce visual biases in peripersonal space, it is also possible that the immobilization we employed in these experiments did not entirely disrupt affordances for acting with the hands. Although participants in the first two experiments were prevented from moving their fingers while wearing the orthosis, presumably disrupting affordances for a power grasping action, the orthosis did not prevent participants from making larger arm movements. An action affordance may still have been available to these participants in which they could use their hand and the orthosis—via arm movements—as a unit to push or swat at nearby objects. Such a relatively large movement would presumably be most sensitive to the same types of temporal visual information that aid fast and forceful power grasp actions (e.g., Thomas, 2015), an action affordance that has repeatedly been associated with enhanced target detection near the hand (e.g., Reed et al., 2010; Thomas, 2013). In Experiment 3, we attempted to further disrupt action affordances involving the hands by introducing an immobilized condition in which the hand was physically attached to the display, disrupting pushing or swatting affordances.

7. Experiment 3

To rule out the possibility that full hand/orthosis action affordances may have played a role in facilitating target detection near the immobilized hands in Experiments 1 and 2, in Experiment 3, we once again asked participants to perform the covert orienting

Table 2
Analysis of variance results for Experiment 2.

Factor	*F*	*p*	η_p^2
Affordance	$F(1,50) = .002$	.967	.000
Target distance	$F(1,50) = 11.347$	.001	.185
Validity	$F(1,50) = 138.400$	> .001	.735
Affordance * target distance	$F(1,50) = .002$	.966	.000
Affordance * validity	$F(1,50) = .005$	.944	.000
Target distance * validity	$F(1,50) = 1.476$	.230	.029
Affordance * target Distance * validity	$F(1,50) = .901$	.347	.018

Fig. 6. Experimental conditions for Experiment 3. A Velcro strip was fixed to the side of the monitor, which attached to the orthosis, further immobilizing the entire arm. Targets were shifted toward the edges of the monitor to accommodate the new hand position.

task while holding either a free or immobilized hand near one of the target locations. In addition to immobilization of the fingers and wrists associated with wearing the orthosis, participants in Experiment 3 were also prevented from making arm movements, presumably suppressing action affordances that may arise from the possibility of swatting motions using the whole arm. With their arms attached to the monitor, participants had no affordances available in which they could use their hands to interact with information presented on the display.

8. Method

8.1. Participants

Another group of 64 undergraduate volunteers from the North Dakota State University participant pool, none of who had participated in Experiments 1 or 2, 53 of whom ultimately provided data for analyses, ran in Experiment 3 for course credit. As with the previous experiments, all participants self-reported as right-handed and had normal or corrected-to-normal vision.

8.2. Stimuli, apparatus, procedure, and design

Experiment 3 was a replication of Experiment 2, using the same task and four hand configurations. Participants again ran through the four hand configurations twice in a randomized order. However, in Experiment 3, the orthosis used to immobilize the hands was attached to the monitor using a Velcro strap, further disrupting participants' ability to perform an action with their hands (see Fig. 6).

Because participants' hands were fixed to the side of the monitor, instead of held next to the target boxes as in Experiments 1 and 2, we shifted the target boxes in Experiment 3 towards the edges of the monitor to maintain the distance between hand and target used in the previous experiments. The boxes were the same size, but were now positioned 8.23° to the left and right of fixation. All other aspects of Experiment 3 were identical to the second experiment.

9. Results and discussion

Four participants made response errors on more than 50% of catch trials and so were dropped from the study and replaced. Another seven participants were dropped from the study for failing to follow the instructions, leaving data from 53 participants for analysis. As in the previous analysis, trials with a reaction time of less than 200 ms or greater than 1000 ms were excluded. This omitted 9.00% of trials from analyses.

Figs. 7 and 8 display mean reaction times to detect targets across conditions. As in the previous experiment, reaction times were submitted to a 2 × 2 × 2 within-subjects ANOVA, with factors of target distance, validity, and affordance. Table 3 provides the results of this analysis. Once again, we found a significant main effect of validity ($F(1,52) = 182.532$, $p < .001$, partial eta squared = .778) as well as a significant main effect of target distance ($F(1,52) = 4.054$, $p = .049$, partial eta squared = .072). No other main effects or interactions were statistically significant, although there was a marginal interaction between target distance and validity. Importantly, we again found that affordance did not interact with any of the other factors, suggesting there was no difference between hands-free and hands-immobilized conditions. Consistent with the findings from our first two experiments, participants showed a general reaction time advantage for detecting targets near, as opposed to far from, their hands regardless of whether they wore the orthosis or not.

Fig. 7. Results from Experiment 3 valid trials: mean reaction time comparisons of target near to target far for Hands-free vs. Hands-Immobilized. Error bars represent ± 1 SEM.

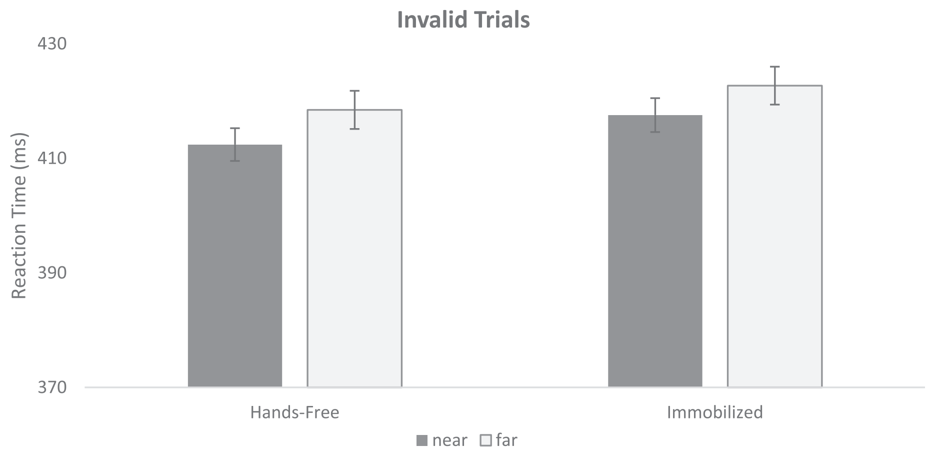

Fig. 8. Results from Experiment 3 invalid trials: mean reaction time comparisons of target near to target far for Hands-free vs. Hands-Immobilized. Error bars represent ± 1 SEM.

Table 3
Analysis of variance results for Experiment 3.

Factor	*F*	*p*	η_p^2
Affordance	$F(1,52) = 2.042$	.159	.038
Target distance	$F(1,52) = 4.054$	.049	.072
Validity	$F(1,52) = 182.532$	> .001	.778
Affordance * target distance	$F(1,52) = .274$	.603	.005
Affordance * validity	$F(1,52) = .548$	.463	.010
Target distance * validity	$F(1,52) = 3.076$	.085	.056
Affordance * target Distance * validity	$F(1,52) = .078$	.781	.002

10. General discussion

Over a decade of research employing a variety of visual cognition paradigms points to a special relationship between the hands' proximity to stimuli and alterations in visual processing (for reviews, see Brockmole et al. (2013) and Tseng, Bridgeman, and Juan (2012)), appealing to the hands' significance for action as a potential explanation for near-hand biases. More recent work also indicates that action affordances play a role in shaping visual processing near the hands (e.g., Thomas, 2015). However, in the current study, across three experiments, we found evidence consistent with the idea that grasp affordances are not essential to facilitating target detection near the palm of the hand. Replicating previous findings (e.g., Reed et al., 2006; Thomas, 2013), participants in each experiment detected targets appearing near the palm of an outstretched hand faster than targets appearing far from the hand. This effect held true when the hand was free to move as well as when the hand was restrained by an orthosis; immobilizing the hand did not eliminate near-hand effects. To the extent that our orthosis manipulation successfully suppressed participants' affordances for acting with the hands, these results suggest that proximity alone is sufficient to facilitate target detection in peripersonal space, and that in-the-moment affordances for grasping are not necessary to obtain this effect.

How can we reconcile the lack of differences between the hands-free and hands-immobilized conditions found in the current study with previous evidence pointing to the importance of grasp affordances in near-hand visual biases (e.g., Reed et al., 2010; Thomas, 2013)? One possibility is that—at least in the case of the simple target detection paradigm—near-hand facilitation is primarily driven by the relative signal boost of bimodal visuotactile neurons preferentially responding to targets appearing close to the palm of the hand (Reed et al., 2006). Our current results, as well as previous findings using the target detection task to investigate power versus precision grasp affordances (Thomas, 2013) are consistent with this attentional prioritization account. While bimodal neurons show selectivity based on object size—i.e., whether an object affords a power or precision grasp—(Fadiga, Fogassi, Gallses, & Rizzolatti, 2000), visuotactile neuronal responses are robust to an arm's restraint and occur even when an observing animal is chemically immobilized and anesthetized (Graziano, Yap, & Gross, 1994). Presumably, the orthosis we employed in this experiment would not interfere with bimodal neural responses to targets appearing near the palm of the hand.

Although the results of the current study suggest affordances for grasping are not a prerequisite for at least some alterations in visual processing near the hands, we recommend exercising caution in attempting to generalize these findings to other paradigms investigating near-hand biases. Recent work suggests that the visual processing changes that occur in peripersonal space when a single hand is placed near a display are markedly different than those associated with gripping a display between both hands—the former involves a focusing of attention near the single hand, while the later leads to a diffusion of attention over the space between the hands (Bush & Vecera, 2014). In addition, recent hybrid accounts of biased vision near the hands suggest that changes in the attentional properties of a task can alter which aspects of visual information—temporal versus spatial—receive preferential processing (e.g., Caplette et al., 2017; Goodhew & Clarke, 2016). The target detection paradigm we employed in the current study is ideal for investigating focused attention, but does not necessarily speak to findings linking specific grasp affordances to dynamic changes in visual processing biases when stimuli are viewed between two hands (Thomas, 2015, 2017).

While previous work suggests that wearing an immobilizing orthosis can introduce near-instantaneous shifts in the neural representation of affordances (Kühn et al., 2014), it is also important to note that short-lived immobilization may not completely eliminate *all* grasp affordance representations. Previous work on altered vision near the hands suggests that observers show visual biases that mirror those observed under hands-near conditions when they merely *imagine* their hands near a display (Davoli & Abrams, 2009), raising the possibility that participants in our study performed a mental simulation consistent with a grasp posture when their hands were immobilized. In addition, top-down instructional set can mediate near-hand attentional prioritization (Garza, Strom, Wright, Roberts, & Reed, 2013). Participants in our experiments received instructions that emphasized hand placement near the screen, which may have inadvertently triggered long-held associations between viewing objects near the palm of the hand and being able to grasp these objects.

Future studies can address these potential limitations in interpreting the current results by introducing longer-term immobilization manipulations that have been shown to more strongly influence affordance representations (e.g., Facchini, Romani, Tinazzi, & Aglioti, 2002; Granert et al., 2011) and/or introducing a manipulation to interfere with participants' ability to imagine acting with their immobilized hands. It is also important for future work to address the question of whether or not the current findings generalize to additional paradigms employing dual, instead of single-hand, manipulations. Nevertheless, the consistent pattern of facilitation near an immobilized hand across these three experiments suggests that physical grasp affordances are not necessary to introduce visual biases in peripersonal space. Moving forward, it is important for researchers interested in near-hand effects to carefully consider what—if any—role action plays in these effects.

11. Notes

All data have been made publicly available via the Open Science Framework and can be accessed at https://osf.io/qvxj7/?view_only=24230ec0f4244086ac15cd9e2a969c04.

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Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.concog.2018.05.001.

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