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Updating perception and action across real-world viewpoint changes

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Abstract

A growing body of research suggests that performing actions can distort the perception of size, distance, and other visual information. These distortions have been observed under a variety of circumstances, and appear to persist in both perception and memory. However, it is unclear whether these distortions persist as observers move to new viewpoints. To address this issue, the present study assessed whether action-specific distortions persist across changes in viewpoint. Participants viewed an object that was projected onto a table, then reached for it with their index finger or a reach-extending tool. After reaching for the object, participants remained stationary or moved to a new viewpoint, then estimated the object's distance from their current viewpoint. When participants remained stationary, using a reach-extending tool led them to report shorter distance estimates. However, when participants moved to a new viewpoint, these distortions were eliminated. Similar effects were observed when participants produced different types of movement, including when participants rotated in place, moved to a new location, or simply walked in place. Together, these findings suggest that action-specific distortions are eliminated when observers move and perform other actions.

Keywords Actions · Tool use · Movement · Spatial updating · Embodied cognition

Introduction

We often assume that our perception provides a veridical view of the world. This view is consistent with much of our daily experience, in which we view and interact with objects with relative ease. Moreover, this view is consistent with many theoretical accounts of perception (e.g., Fodor, 1983; Pylyshyn, 1999). According to these accounts, visual perception is insulated from other cognitive processes, including observers' knowledge, expectations, and physical abilities (see also Firestone, 2013; Firestone & Scholl, 2016). In contrast to this view, a growing body of research suggests that performing actions can distort our visual perception of the world. For example, wearing a heavy backpack leads people to overestimate the steepness of hills (Bhalla & Proffitt, 1999), successfully hitting a target leads people to overestimate the size of the target (Wesp, Cichello, Gracia, & Davis, 2004), and using a reach-extending tool leads people to underestimate the distances to objects (Witt, Proffitt, & Epstein, 2005). Together, these findings are consistent with the action-specific account of perception (Proffitt, 2006; Witt, 2011). According to this account, visual perception is scaled by observers' physical abilities, allowing them to perceive the world in terms of their ability to interact with it.

Although the action-specific account of perception differs from many theoretical accounts of perception, it shares many features with Gibson's (1979) theory of affordances. According to Gibson, *affordances* are invariant properties of the environment that specify which actions an observer can perform. For example, level ground affords walking, while sufficiently steep terrain does not. Much like the action-specific account of perception, Gibson argued that affordances can be perceived directly. Indeed, a number of studies have found that observers can perceive affordances for walking (Warren & Whang, 1987), sitting (Mark, Balliett, Craver, Douglas, & Fox, 1990), and stair climbing (Mark, 1987; Warren, 1984). In many of these cases, observers can more accurately perceive affordances when they are free to move and observe objects from new viewpoints (Jiang & Mark, 1994; Mark, 1987; Mark et al., 1990; Mark, Jiang, King, & Paasche, 1999). However, most studies of action-specific perception measure visual perception from a fixed viewpoint. In the present study, we assessed whether action-specific distortions persist as observers move to new viewpoints. As we

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demonstrate, this issue has important implications not only for the action-specific perception literature, but for theoretical accounts of perception in general.

Action-specific perception

The earliest evidence for action-specific distortions comes from studies of slant perception. For example, observers overestimate the steepness of hills when viewing them from the top, which reflects the fact that steep hills are harder to descend than to ascend (Proffitt, Bhalla, Gossweiler, & Midgett, 1995). This suggests that the effort associated with climbing a hill can influence the perception of slant. To test whether this was the case, Bhalla and Proffitt (1999) had participants stand at the bottom of a hill while wearing a heavy backpack, then asked them to estimate the steepness of the hill. Compared to participants who viewed the hill without a backpack, those who wore a heavy backpack overestimated the steepness of the hill. Thus, the effort of wearing a backpack appeared to distort participants' slant perception. Similar findings have been observed using other manipulations of effort. For example, observers who are fatigued from running or in poor physical health also overestimate the steepness of hills (Bhalla & Proffitt, 1999; Proffitt et al., 1995). These findings suggest that physical effort can distort observers' slant perception, with increasing effort leading to increased perception of slant.

Since Bhalla and Proffitt's (1999) original findings, a number of studies have observed similar distortions of visual perception. For example, observers overestimate distances on hills compared to level ground, and further overestimate distances on hills when viewing them from the top (Stefanucci, Proffitt, Banton, & Epstein, 2005). This suggests that the effort associated with climbing a hill can also influence the perception of distance. More direct evidence for these findings comes from studies that directly manipulate effort. For example, when observers wear a heavy backpack, they also overestimate distances on level ground (Proffitt, Stefanucci, Banton, & Epstein, 2003). Similarly, when observers walk on a treadmill or throw a heavy ball at a target, they overestimate the distance to the target (Proffitt et al., 2003; Witt, Proffitt, & Epstein, 2004, 2010). However, these effects appear to be specific to observers' intentions. For example, the effort associated with throwing a heavy ball only influences observers' distance perception when they intend to throw the ball (Witt et al., 2004, 2010). In each of these cases, the effort associated with performing an action appears to distort observers' distance perception, with increasing effort leading to increased perception of distance.

In addition to effort, there is evidence that other physical abilities can influence visual perception. In one study, Wesp et al. (2004) had participants throw darts at a target, then asked them to estimate the size of the target. Participants who were more successful at hitting the target overestimated its size, suggesting that performance on this task distorted participants' size perception. Similar findings have been observed for performance in many sports. For example, softball players who are hitting better in a game overestimate the size of the ball (Witt & Proffitt, 2005), and golfers who are playing better in a round overestimate the size of the hole (Witt, Linkenauger, Bakdash, & Proffitt, 2008). These effects are not limited to athletic performance, but also occur for simple actions such as grasping. For example, when an object can be easily grasped with one's dominant hand, participants underestimate both the size (Linkenauger, Witt, Bakdash, Stefanucci, & Proffitt, 2009; Linkenauger, Witt, & Proffitt, 2011) and the distance to the object (Linkenauger, Witt, Stefanucci, Bakdash, & Proffitt, 2009). These findings suggest that the ease of performing many actions can distort the perception of size and distance, with better performance leading observers to perceive objects as easier to interact with.

The previous findings suggest that observers' physical abilities can influence their visual perception. However, using tools can also influence observers' physical abilities, allowing them to perform actions that might not otherwise be possible. Consistent with this prediction, there is evidence that tool use can also influence visual perception. For example, Witt et al. (2005) had participants reach for objects with a reach-extending tool, then asked them to estimate the distance to the objects. Compared to participants who did not hold a tool, those who reached with a tool underestimated the distance to the objects, suggesting that reaching with a tool compressed participants' distance perception (see also Witt & Proffitt, 2008). Similar effects are observed when observers use a tool that remotely extends their reach. For example, when observers point to objects using a laser pointer, they also underestimate the distance to the objects (Davoli, Brockmole, & Witt, 2012). Based on these findings, the effects of tool use are not limited to cases in which participants physically interact with objects. Instead, these distortions can be observed when participants simply intend to perform an action. In line with this suggestion, several studies have shown distortions of visual perception when participants intend to reach for an object but do not interact with it (Davoli et al., 2012; Vishton et al., 2007; Witt & Proffitt, 2008; see also Davoli & Abrams, 2009).

Spatial updating

Although evidence for action-specific distortions comes from a variety of sources, these distortions have largely been studied under stationary viewing conditions. This differs from many real-world situations, in which observers are free to move and observe objects from multiple viewpoints. In such cases, observers' spatial knowledge must be updated to reflect the changing spatial relationships between themselves and the environment. This process, known as *spatial updating,* has been observed in a number of spatial reasoning studies. For example, when children imagine an array of objects rotating in place, they have difficulty identifying where individual objects would be located. However, when children imagine themselves moving to a new viewpoint, their performance on this task improves (Huttenlocher & Presson, 1973, 1979). Similar findings have been observed for adults, suggesting that these effects are not specific to children (Presson, 1982). Moreover, when children physically move to a new viewpoint, their performance on this task further improves (Huttenlocher & Presson, 1973). Thus, observers' spatial knowledge appears to be updated as they move to new viewpoints.

More direct evidence for spatial updating comes from studies that compare physical and imagined movement. In one study, Rieser (1989) had participants view an array of objects, then asked them to rotate in place and point to the locations of objects from memory. When participants rotated in place, their pointing estimates were faster and more accurate than when they simply imagined rotating. Thus, moving to a new viewpoint appeared to update participants' spatial knowledge of the array. Similar findings have been observed using other types of movement (Easton & Sholl, 1995; Farrell & Robertson, 1998; Presson & Montello, 1994), including when movement of an observer is compared with movement of an array of objects (Simons & Wang, 1998; Wang & Simons, 1999). Moreover, a number of studies have found that physical movement is difficult to ignore, even when this movement is irrelevant to observers' task. For example, when observers move to a new viewpoint but are asked to ignore this movement, they have difficulty walking and pointing to the locations of objects from memory (Farrell & Robertson, 1998; Farrell & Thomson, 1998; May & Klatzky, 2000). This suggests that the spatial updating process is automatic, and occurs continuously as observers move throughout the environment.

The present study

A growing body of research suggests that performing actions can distort the perception of size, distance, and other visual information (Proffitt, 2006; Witt, 2011). However, most studies of action-specific perception measure visual perception from a fixed viewpoint. As evidence from the spatial cognition literature suggests, observers' spatial knowledge is continuously updated as they move throughout the environment (Easton & Sholl, 1995; Farrell & Robertson, 1998; Presson & Montello, 1994; Rieser, 1989). However, it is unclear whether action-specific distortions are updated in a similar fashion. The ability to reach, throw, and perform other actions is often specific to the observers' viewpoint, and may change as soon as observers have moved to a new viewpoint. Because observers' physical abilities must also be updated to reflect these changes, it is important to assess whether action-specific distortions persist as observers move to new viewpoints. On one hand, action-specific distortions may persist in visual perception, even after observers have moved to a new viewpoint. Alternatively, action-specific distortions may no longer be observed once observers move to a new viewpoint. Both outcomes would challenge the assumption that perception provides a veridical and unchanging view of the world.

Importantly, a number of studies suggest that action-specific distortions can persist in both perception and memory. For example, Vishton et al. (2007) found that reaching for a visual illusion reduced the perceived size of the illusion. These effects were observed for up to several minutes after participants completed this action, suggesting that action-specific distortions can persist in perception for short durations. Several studies also suggest that action-specific distortions can persist in memory. For example, successfully hitting a target leads observers to recall the target as larger (Wesp et al., 2004; Witt et al., 2008; Witt & Proffitt, 2005), and using a reach-extending tool leads observers to recall objects as closer (Davoli et al., 2012). Similar findings have been observed when observers move and interact with multiple objects. For example, when participants pick up an array of objects, they recall shorter distances between all objects in the array (Clement, Radvansky, & Brockmole, 2017; Thomas, Davoli, & Brockmole, 2013). These findings suggest that action-specific distortions may persist in perception and memory, even after observers have completed an action. If this is the case, action-specific distortions may also persist as observers move to new viewpoints.

In contrast to these findings, a number of studies suggest that action-specific distortions may be continuously updated as a function of observers' abilities and intentions. For example, throwing a heavy ball at a target leads observer to overestimate the distance to the target, but only when they intend to throw the ball (Witt et al., 2004, 2010). Similarly, using a reach-extending tool leads observers to underestimate the distances to objects, but only when they intend to reach with the tool (Witt et al., 2005). Other studies have found that simply intending to reach for an object can distort visual perception, even when participants do not physically interact with the object (Davoli et al., 2012; Vishton et al., 2007; Witt & Proffitt, 2008; see also Davoli & Abrams, 2009). Moreover, action-specific distortions appear to be sensitive to changes in observers' intentions. For example, when participants intend to throw a heavy ball at a target but are instead asked to walk to the target, these distortions are no longer observed (Witt et al., 2010). Together, these findings suggest that visual perception may be continuously updated as observers move and perform other actions. If this is the case, action-specific distortions may not persist as observers move to new viewpoints.

Based on the previous findings, it is unclear whether action-specific distortions persist as observers move to new viewpoints. To address this issue, the present study assessed whether action-specific distortions persist across changes in viewpoint. Participants viewed an object that was projected onto a table, then reached for it with their index finger or a reach-extending tool. After reaching for the object, participants remained stationary or moved to a new viewpoint, then estimated the object's distance. If reaching with a tool compresses participants' distance perception, using a reach-extending tool should lead participants to report shorter distance estimates (Davoli et al., 2012; Witt & Proffitt, 2008; Witt et al., 2005). More importantly, these effects should depend on whether participants move to a new viewpoint. If action-specific distortions persist across changes in viewpoint, these distortions should be observed regardless of whether participants move or remain stationary. However, if action-specific distortions do not persist across changes in viewpoint, these distortions should only be observed when participants remain stationary.

Experiments 1A and 1B

Previous evidence suggests that reaching with a tool can compress participants' distance perception (e.g., Witt et al., 2005). However, a growing number of studies have failed to replicate many action-specific distortions (e.g., Cooper, Sterling, Bacon, & Bridgeman, 2012; Durgin et al., 2009; Shaffer & Flint, 2011; Woods, Philbeck, & Danoff, 2009), leading some researchers to question the validity of these effects. Thus, before assessing whether action-specific distortions persist across changes in viewpoint, we sought to replicate the effects of tool use on distance perception when observers remain stationary. Specifically, we conducted two identical replication experiments to ensure that these effects can be observed under a consistent set of conditions. Participants viewed an object that was projected onto a table, then reached for it using their index finger or a reach-extending tool. Participants then estimated the object's distance. If physical abilities influence visual perception, participants should report shorter distance estimates when they reach with a tool. However, if physical abilities do not influence visual perception, reaching with a tool should not influence participants' distance estimates.

Like many studies of action-specific perception, participants in the present study provided verbal reports of distance. We selected this method for several reasons. First, verbal reports are a common method for estimating distance, both in the laboratory and in real-world situations. They are easy to provide and require no special equipment, making them ideal for estimating distance as observers move to new viewpoints. Verbal reports are also sensitive to many action-specific distortions (e.g., Davoli et al., 2012; Proffitt et al., 2003; Stefanucci et al., 2005; Witt et al., 2004, 2005). Together, these advantages make verbal reports an ideal method for the present study. However, there are several disadvantages to using verbal reports. For example, observers may have different knowledge about the length of various distance units, which can influence the accuracy of their distance estimates (Montello, 1991). To address this issue, participants in the present study were instructed to provide estimates in the unit they were most familiar with. To account for variability in participants' knowledge of distance units, tool use was also manipulated within participants. Thus, if participants have incorrect knowledge about a particular distance unit, this knowledge should be equal across conditions.

Methods

Participants In a previous study on which our methods are based, data were collected from a total of 16 participants in a within-subjects design (Witt et al., 2005). However, because a number of studies have failed to replicate many action-specific distortions, we increased our sample size to 36 participants. Assuming a small effect size ($f = 0.1$) and a moderate correlation between levels of our within-subjects variables ($\rho = 0.5$), an a priori power analysis indicated that this sample size would be sufficient to detect a main effect of tool use at 80% statistical power. As a result, two groups of 36 University of Notre Dame undergraduates participated for $15 or course credit. Five participants were excluded from Experiment 1A and four were excluded from Experiment 1B for one or more of the reasons listed in Table 1.

Apparatus and stimuli The same apparatus and stimuli were used in Experiments 1A and 1B. The experiments were conducted on a 244 × 107 cm oval table positioned 74 cm above the floor. The table was located in a typical laboratory environment, with no objects in the space immediately surrounding the table. Stimuli were projected onto the table using a projector facing downward from the ceiling. Stimuli consisted of four objects (circle, square, diamond, cross). Stimuli were presented in black and subtended 2.5 cm in diameter. To minimize landmarks and other visual cues, the table was covered with a blank white sheet. An identical metal handle was attached to each end of the table. One of the handles served as a reference point for participants' distance estimates, and participants held this handle with their non-dominant hand. For half the trials, participants held a 122-cm metal baton with their dominant hand (see Fig. 1).

Procedure and design The same experimental procedure was used in Experiments 1A and 1B. Participants stood at one end of the table while holding the nearest handle. At the beginning of each trial, an object was projected onto the table. An experimenter instructed participants to reach for the object using

Table 1 Exclusion criteria and number of participants excluded from each experiment

Exclusion rule	Exp. 1A	Exp. 1B	Exp. 2	Exp. 3	Exp. 4A	Exp. 4B	Exp. 5
Qualified as a statistical outlier	0 (0%)	0 (0%)	1 (2.78%)	1 (2.78%)	0 (0%)	0 (0%)	1 (2.78%)
Failed to complete a full block of trials	0 (0%)	0 (0%)	2 (5.56%)	1 (2.78%)	0 (0%)	0 (0%)	1 (2.78%)
Did not touch objects with the baton	3 (8.33%)	4 (11.1%)	2 (5.56%)	0 (0%)	3 (8.33%)	5 (13.9%)	2 (5.56%)
Touched objects after moving to a new viewpoint	1 (2.78%)	0 (0%)	0 (2.78%)	1 (2.78%)	1 (2.78%)	0 (0%)	0 (0%)
Did not look at objects while estimating distance	1 (2.78%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Stood at an incorrect location	0 (0%)	0 (0%)	0 (0%)	1 (2.78%)	0 (0%)	0 (0%)	0 (0%)
Experimenter entered responses incorrectly	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (2.78%)	0 (0%)	0 (0%)
Total excluded	5 (13.9%)	4 (11.1%)	3 (8.33%)	4 (11.1%)	5 (13.9%)	5 (13.9%)	4 (11.1%)

Notes. Participants could be excluded for multiple reasons. Statistical outliers provided average distance estimates that exceeded ±3 standard deviations from the mean

their index finger or the baton, and to touch the object if it was within reach. If the object was beyond reach, participants simply pointed to it. Participants were instructed not to lean forward while reaching. After reaching for the object, participants estimated the object's distance from the handle they were currently holding. Participants made all estimates in inches or centimeters (whichever they were more familiar with), and no feedback was provided on the accuracy of their estimates. An experimenter then recorded participants' distance estimates.

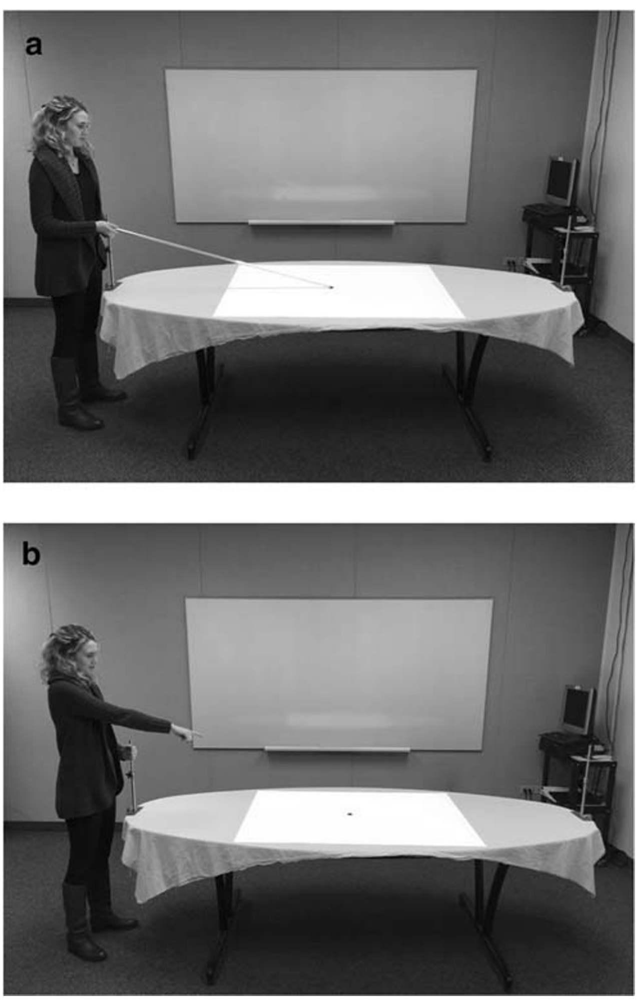

Fig. 1 The experimental setup used in the present study. (**A**) A participant reaching with the baton. (**B**) A participant pointing with her index finger

Participants completed two blocks of trials: one with the baton, and one without the baton. Each block consisted of 40 trials, for a total of 80 trials. The four objects were presented randomly and equally often, with each object appearing once before an object could be repeated. The same object could not appear twice in a row. Objects were presented at the following distances: 86.4 cm, 88.9 cm, 94.0 cm, 96.5 cm, 101.6 cm, 104.1 cm, 109.2 cm, 111.8 cm, 116.8 cm, 119.4 cm, 124.5 cm, 127.0 cm, 132.1 cm, 134.6 cm, 139.7 cm, 142.2 cm, 147.3 cm, 149.9 cm, 154.9 cm, and 157.5 cm. Although all distances were beyond reach when participants pointed with their index finger, all distances were within reach when participants held the baton. All distances were symmetric around the midpoint of the table, so that objects were equally reachable from both ends of the table. Distances were presented randomly and equally often, with the same restrictions used for object randomization. Each distance was presented twice within a block. Block order was counterbalanced across participants, with half of participants holding the baton for the first block and half holding the baton for the second block. Participants' viewing position was also counterbalanced across participants, with half of participants standing at one end of the table and half standing at the other end of the table.

Results

Prior to analysis, all distance estimates were converted to centimeters. To test whether action-specific distortions could be observed when participants remained stationary, we analyzed average distance estimates using a 2 (experiment: Experiment 1A, Experiment 1B) × 2 (tool use: baton, no tool) × 20 (distance: 86.4 cm to 157.5 cm) mixed-model analysis of variance (ANOVA). Experiment was entered as a between-subjects variable, and tool use and distance were entered as within-subjects variables. Unsurprisingly, the analysis revealed a significant main effect of distance, with participants' distance estimates increasing at longer distances, F (19, 1,159) = 587.90, $p < .001$, $\eta_p^2 = .900$. More importantly, there was a significant main effect of tool use, F (1, 61) = 8.09, $p = .006$, $\eta_p^2 = .117$, with participants providing shorter distance estimates when they reached with the baton (M = 115.8 cm, SD = 19.2 cm) compared to their index finger, (M = 119.3 cm, SD = 22.0 cm). Thus, reaching with a tool influenced participants' distance estimates. There was also a significant interaction between tool use and distance, with participants making increasingly shorter distance estimates when they reached with the baton compared to their index finger, F (19, 1159) = 1.62, $p = .046$, $\eta_p^2 = .026$. Thus, the magnitude of these distortions increased at longer distances. There were no significant effects of experiment, all ps ≥ .358. Thus, the effects of tool use did not differ between Experiments 1A and 1B. Together, these results suggest that reaching with a tool compressed participants' distance perception (see Fig. 2).

Discussion

In Experiments 1A and 1B, we replicated the effects of tool use on distance perception when participants remained stationary. In both cases, using a reach-extending tool led participants to report shorter distance estimates. Thus, consistent with previous evidence, reaching with a tool appeared to compress participants' distance perception (Davoli et al., 2012; Witt & Proffitt, 2008; Witt et al., 2005). Moreover, consistent with some previous studies, the magnitude of these distortions increased at longer distances (Davoli et al., 2012). Having demonstrated these effects, our second experiment examined action-specific distortions when observers move to a new viewpoint.

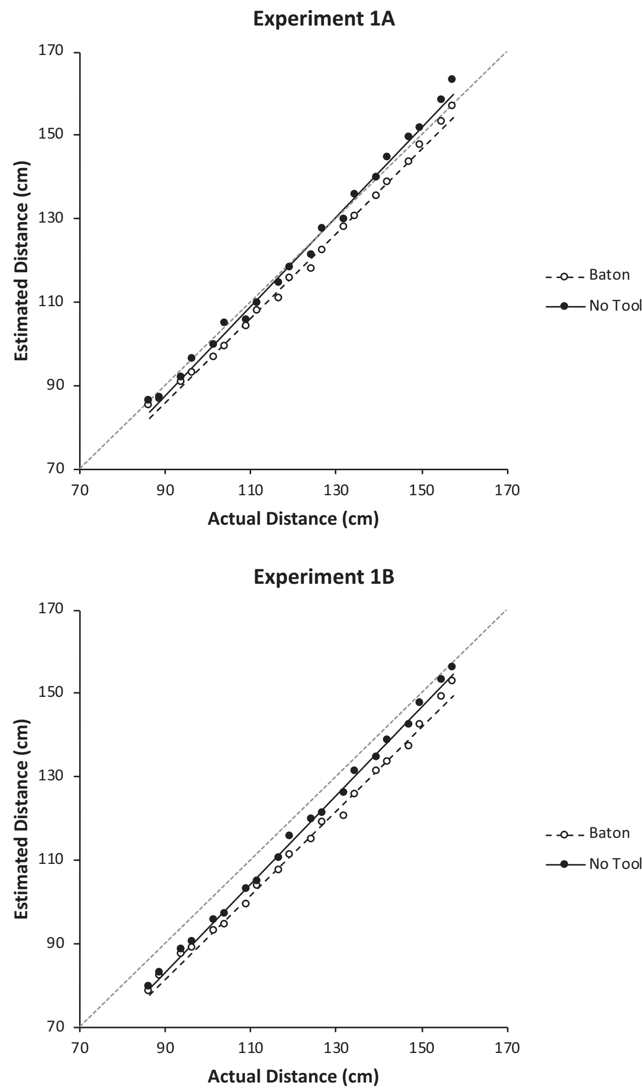

Fig. 2 Average distance estimates plotted as a function of actual distance in Experiments 1A and 1B. Dashed and solid lines represent least-squares regression functions for the baton and no-tool conditions. The dotted line represents perfect accuracy

Experiment 2

In Experiments 1A and 1B, reaching with a tool appeared to compress participants' distance perception. In Experiment 2, we sought to assess whether these action-specific distortions persist when observers move to a new viewpoint. Participants viewed an object that was projected onto a table, then reached for it using their index finger or a reach-extending tool. Participants then moved to a new viewpoint at the opposite end of the table and estimated the object's distance. If action-specific distortions persist when observers move to a new viewpoint, reaching with a tool should influence participants' distance estimates. However, if these distortions do not persist when observers move to a new viewpoint, reaching with a tool should not influence participants' distance estimates. Assuming that action-specific distortions are observed in this experiment, there are at least two ways in which these distortions may occur. If visual perception is distorted relative to observers' current viewpoint, participants should report shorter distance estimates when they reach with a tool. However, if visual perception is distorted relative to observers' original viewpoint, participants should report longer distance estimates when they reach with a tool.

Methods

Participants A new group of 36 University of Notre Dame undergraduates participated for $15 or course credit. Three participants were excluded for one or more of the reasons listed in Table 1.

Apparatus and stimuli The apparatus and stimuli were identical to those in Experiments 1A and 1B.

Procedure and design Participants stood at one end of the table while holding the nearest handle. At the beginning of each trial, an object was projected onto the table. Participants reached for the object using their index finger or the baton, and touched the object if it was within reach. After reaching for the object, participants walked to the opposite end of the table and held the nearest handle. Afterward, participants estimated the object's distance from the handle they were currently holding. Participants continued to hold the baton as they moved and estimated distance. All other details of the experimental procedure were identical to those in Experiments 1A and 1B.

Results

Prior to analysis, all distance estimates were converted to centimeters. To test whether action-specific distortions could be observed when participants moved to a new viewpoint, we analyzed average distance estimates using a 2 (tool use: baton, no tool) × 20 (distance: 86.4 cm to 157.5 cm) repeated-measures ANOVA. As in the previous experiments, there was a significant main effect of distance, with participants' distance estimates increasing at longer distances, F (19, 608) = 224.90, p < .001, η_p^2 = .875. However, there was neither a significant main effect of tool use, F (1, 32) = 0.39, p = .535, η_p^2 = .012, nor a significant interaction between tool use and distance, F (19, 608) = 1.23, p = .230, η_p^2 = .037. A Bayes factor analysis (Rouder, Speckman, Sun, Morey, & Iverson, 2009) indicated that the null hypothesis was 6.14 times more likely to account for the observed data than the alternative hypothesis that participants' distance estimates would differ between the baton and no-tool conditions. Together, these results suggest that action-specific distortions were eliminated when participants moved to a new viewpoint (see Fig. 3).

Discussion

In Experiment 2, we found no evidence for action-specific distortions. When participants moved to a new viewpoint, using a reach-extending tool did not influence their distance estimates. Thus, in contrast to the previous experiments, reaching with a tool did not appear to compress participants' distance perception. Notably, participants in Experiment 2 always estimated distance from a new viewpoint. Thus, although action-specific distortions were observed when participants remained stationary, they were eliminated when participants moved to a new viewpoint. Together, these findings suggest that action-specific distortions do not persist as observers move to new viewpoints.

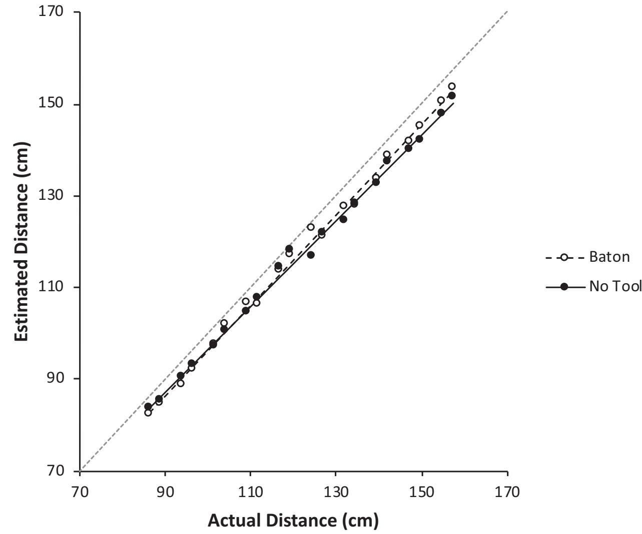

Fig. 3 Average distance estimates plotted as a function of actual distance in Experiment 2. Dashed and solid lines represent least-squares regression functions for the baton and no-tool conditions. The dotted line represents perfect accuracy

Experiment 3

In Experiment 2, action-specific distortions were eliminated when participants moved to a new viewpoint. However, participants always reached and estimated distance from different viewpoints. Thus, it is possible that the previous findings were due to viewpoint dependence. According to the spatial cognition literature, observers often form viewpoint-dependent representations of the environment. In such cases, spatial knowledge is more accessible when observers' current viewpoint matches a previously studied viewpoint (Diwadkar & McNamara, 1997; Shelton & McNamara, 1997; Sholl & Nolin, 1997). If the previous findings were due to viewpoint dependence, action-specific distortions may persist when observers move and return to their original viewpoint. In Experiment 3, we sought to assess whether the previous findings were due to viewpoint dependence. Participants viewed an object that was projected onto a table, then reached for it using their index finger or a reach-extending tool. Participants then walked completely around the table, returned to their original viewpoint, and estimated the object's distance. If action-specific distortions persist when observers move and return to their original viewpoint, reaching with a tool should influence participants' distance estimates. However, if these distortions do not persist when observers move and return to their original viewpoint, reaching with a tool should not influence participants' distance estimates.

Methods

Participants A new group of 36 University of Notre Dame undergraduates participated for $15 or course credit. Four participants were excluded for one or more of the reasons listed in Table 1.

Apparatus and stimuli The apparatus and stimuli were identical to those in Experiments 1A and 1B.

Procedure and design Participants stood at one end of the table while holding the nearest handle. At the beginning of each trial, an object was projected onto the table. Participants reached for the object using their index finger or the baton, and touched the object if it was within reach. After reaching for the object, participants walked completely around the table, returned to their original viewing position, and held the nearest handle. Afterward, participants estimated the distance of the object from the handle they were currently holding. Participants continued to hold the baton as they moved and estimated distance. All other details of the experimental procedure were identical to those in Experiments 1A and 1B.

Results

Prior to analysis, all distance estimates were converted to centimeters. To test whether action-specific distortions could be observed when participants moved and returned to their original viewpoint, we analyzed average distance estimates using a 2 (tool use: baton, no tool) × 20 (distance: 86.4 cm to 157.5 cm) repeated-measures ANOVA. As in the previous experiments, there was a significant main effect of distance, with participants' distance estimates increasing at longer distances, $F(19, 589) = 394.44$, $p < .001$, $\eta_p^2 = .927$. However, there was neither a significant main effect of tool use, $F(1, 31) = 0.47$, $p = .498$, $\eta_p^2 = .015$, nor a significant interaction between tool use and distance, $F(19, 589) = 0.85$, $p = .643$, $\eta_p^2 = .027$. A Bayes factor analysis indicated that the null hypothesis was 5.81 times more likely to account for the data than the alternative hypothesis that participants' distance estimates would differ between the baton and no-tool conditions. Together, these results suggest that action-specific distortions were eliminated when participants moved and returned to their original viewpoint (see Fig. 4).

Discussion

In Experiment 3, we again found no evidence for action-specific distortions. When participants moved and returned to their original viewpoint, using a reach-extending tool did not influence their distance estimates. Thus, reaching with a tool did not appear to compress participants' distance perception. Notably, participants in Experiment 3 always reached and estimated distance from the same viewpoint. Thus, the present results were not due to viewpoint dependence, and could be observed when participants returned to their original viewpoint. Together, these findings suggest that action-specific distortions do not persist as observers move throughout the environment.

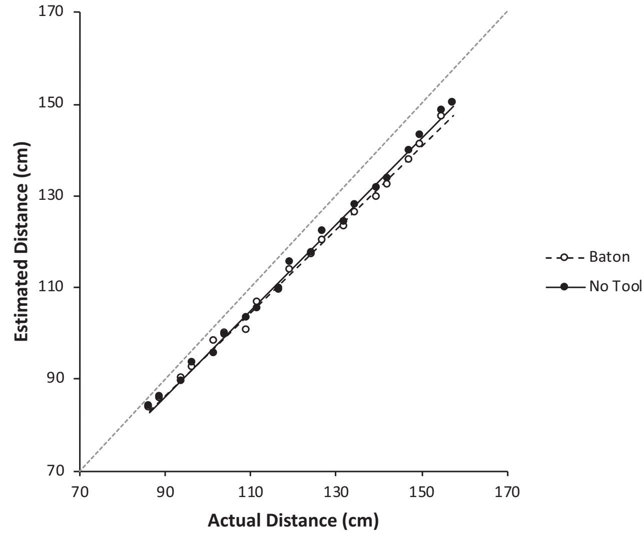

Fig. 4 Average distance estimates plotted as a function of actual distance in Experiment 3. Dashed and solid lines represent least-squares regression functions for the baton and no-tool conditions. The dotted line represents perfect accuracy

Experiment 4A and 4B

In Experiment 3, action-specific distortions were eliminated when participants moved and returned to their original viewpoint. If action-specific distortions do not persist as observers move throughout the environment, these distortions may also be eliminated when observers produce different types of movement. When observers move to new viewpoints, this movement involves both rotation and translation relative to the surrounding environment. Although these types of movement involve different spatial processes (e.g., Rieser, 1989), both types of movement have been shown to produce spatial updating (Easton & Sholl, 1995; Farrell & Robertson, 1998; Presson & Montello, 1994). If action-specific distortions do not persist as observers move throughout the environment, these distortions may also be eliminated when participants rotate in place or move to a different location. In Experiments 4A and 4B, we sought to assess whether action-specific distortions persist when observers produce different types of movement. Participants viewed an object that was projected onto a table, then reached for it using their index finger or a reach-extending tool. Half of participants rotated in place, while the other half took a step backward. Participants then returned to their original viewpoint and estimated the object's distance. If action-specific distortions persist when observers produce different types of movement, reaching with a tool should influence participants' distance estimates. However, if these distortions do not persist when observers produce different types of movement, reaching with a tool should not influence participants' distance estimates.

Methods

Participants Two new groups of 36 University of Notre Dame undergraduates participated for $15 or course credit. Five participants were excluded from Experiment 4A and five were excluded from Experiment 4B for one or more of the reasons listed in Table 1.

Apparatus and stimuli The apparatus and stimuli were identical to those in Experiments 1A and 1B. Because one end of the table was closer to the wall than the other, it was not possible to counterbalance participants' viewing position without participants bumping into the wall. As a result, all participants stood at the same end of the table. To indicate where participants should move, a line of tape was placed on the floor 91 cm from this end of the table.

Procedure and design Participants stood at one end of the table while holding the nearest handle. At the beginning of each trial, an object was projected onto the table. Participants reached for the object using their index finger or the baton, and touched the object if it was within reach. After reaching for the object, participants performed one of two actions. Participants in Experiment 4A ($n = 31$) turned around once while standing in place. Participants in Experiment 4B ($n = 31$) took a step backward until they were standing behind the line of tape. Participants then returned to their original viewing position and held the nearest handle. Afterward, participants estimated the distance of the object from the handle they were currently holding. Participants continued to hold the baton as they moved and estimated distance. All other details of the experimental procedure were identical to those in Experiments 1A and 1B.

Results

Prior to analysis, all distance estimates were converted to centimeters. To test whether action-specific distortions could be observed when participants rotated in place or took a step backward, we analyzed average distance estimates using a 2 (experiment: Experiment 4A, Experiment 4B) × 2 (tool use: baton, no tool) × 20 (distance: 86.4 cm to 157.5 cm) mixed-model ANOVA. Experiment was entered as a between-subjects variable, and tool use and distance were entered as within-subjects variables. As in the previous experiments, there was a significant main effect of distance, with participants' distance estimates increasing at longer distances, F (19, 1,140) = 392.70, $p < .001$, $\eta_p^2 = .867$. There was also a significant two-way interaction between experiment and distance, with participants in Experiment 4B providing increasingly shorter distance estimates compared to participants in Experiment 4A, F (19, 1,140) = 1.90, $p = .011$, $\eta_p^2 = .031$. However, there was neither a significant main effect of tool use, F (1, 60) = 2.61, $p = .111$, $\eta_p^2 = .042$, nor a significant interaction between tool use and distance, F (19, 1,140) = 1.39, $p = .722$, $\eta_p^2 = .013$. A Bayes factor analysis indicated that the null hypothesis was 2.49 times more likely to account for the data than the alternative hypothesis that participants' distance estimates would differ between the baton and no-tool conditions. No other effects were significant, all $ps \geq .123$. Together, these results suggest that action-specific distortions were eliminated when participants rotated in place or took a step backward (see Fig. 5).

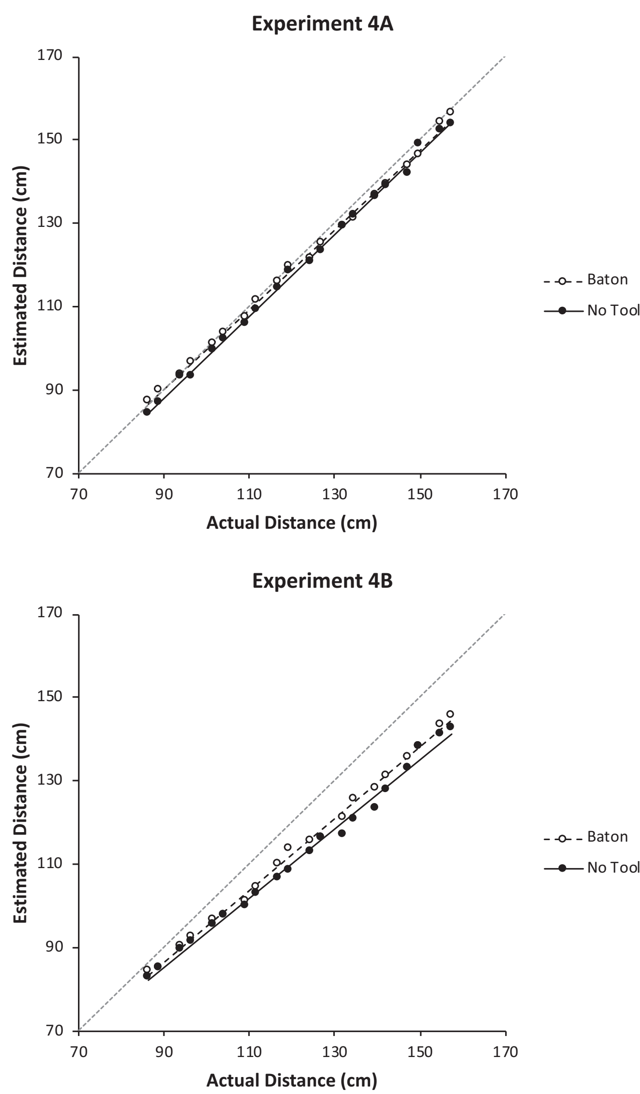

Fig. 5 Average distance estimates plotted as a function of actual distance in Experiments 4A and 4B. Dashed and solid lines represent least-squares regression functions for the baton and no-tool conditions. The dotted line represents perfect accuracy

Discussion

In Experiments 4A and 4B, we again found no evidence for action-specific distortions. When participants rotated in place or took a step backward, using a reach-extending tool did not influence their distance estimates. Thus, reaching with a tool did not appear to compress participants' distance perception. Notably, participants in Experiments 4A and 4B always reached and estimated distance from the same viewpoint. Thus, consistent with the previous experiment, the present results were not due to viewpoint dependence. Again, these findings suggest that action-specific distortions do not persist as observers move throughout the environment.

Experiment 5

In Experiments 4A and 4B, action-specific distortions were eliminated when participants rotated in place or moved to a new location. However, participants always performed another motor action before estimating distance. Thus, it is possible that the previous findings were due to a form of dual-task interference. According to the action-specific perception literature, performing other actions can interfere with many action-specific distortions. For example, simply intending to reach for an object can distort visual perception (Davoli et al., 2012; Vishton et al., 2007; Witt & Proffitt, 2008; see also Davoli & Abrams, 2009). However, when observers grasp another object during this intended action, these action-specific distortions are no longer observed (Witt & Proffitt, 2008). If the previous findings were due to dual-task interference, action-specific distortions may also be eliminated when observers perform other actions. In Experiment 5, we sought to assess whether action-specific distortions persist when observers perform any motor action. Participants viewed an object that was projected onto a table, then reached for it using their index finger or a reach-extending tool. Participants then walked in place and estimated the object's distance. If action-specific distortions persist when observers walk in place, reaching with a tool should influence participants' distance estimates. However, if these distortions do not persist when observers walk in place, reaching with a tool should influence participants' distance estimates.

Methods

Participants A new group of 36 University of Notre Dame undergraduates participated for $15 or course credit. Four participants were excluded for one or more of the reasons listed in Table 1.

Apparatus and stimuli The apparatus and stimuli were identical to those in Experiments 1A and 1B.

Procedure and design Participants stood at one end of the table while holding the nearest handle. At the beginning of each trial, an object was projected onto the table. Participants reached for the object using their index finger or the baton, and touched the object if it was within reach. After reaching for the object, participants took five steps in place. Afterward, participants estimated the object's distance from the handle they were currently holding. Participants continued to hold the baton as they moved and estimated distance. All other details of the experimental procedure were identical to those in Experiments 1A and 1B.

Results

Prior to analysis, all distance estimates were converted to centimeters. To test whether action-specific distortions could be observed when participants walked in place, we first analyzed average distance estimates using a 2 (tool use: baton, no tool) × 20 (distance: 86.4 cm to 157.5 cm) repeated-measures ANOVA. As in the previous experiments, there was a significant main effect of distance, with participants' distance estimates increasing at longer distances, F (19, 589) = 217.54, $p <$ .001, η_p^2 = .875. However, there was neither a significant main effect of tool use, F (1, 31) = 0.98, p = .331, η_p^2 = .031, nor a significant interaction between tool use and distance, F (19, 589) = 0.72, p = .803, η_p^2 = .023. A Bayes factor analysis indicated that the null hypothesis was 4.57 times more likely to account for the data than the alternative hypothesis that participants' distance estimates would differ between the baton and no-tool conditions. Together, these results suggest that action-specific distortions were eliminated when participants walked in place (see Fig. 6).

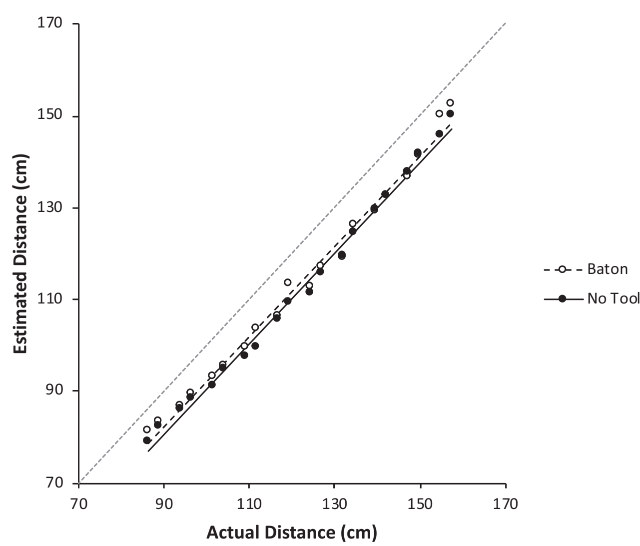

Fig. 6 Average distance estimates plotted as a function of actual distance in Experiment 5. Dashed and solid lines represent least-squares regression functions for the baton and no-tool conditions. The dotted line represents perfect accuracy

Discussion

In Experiment 5, we again found no evidence for action-specific distortions. When participants walked in place, using a reach-extending tool did not influence their distance estimates. Thus, reaching with a tool did not appear to distort participants' distance perception. Notably, participants in Experiment 5 did not rotate or move to a new location. Thus, the present results were due to a form of dual-task interference, and could be observed when participants perform any motor action. Together, these findings suggest that action-specific distortions do not persist as observers move and perform other actions.

General discussion

A growing body of research suggests that performing actions can distort the perception of size, distance, and other visual information (Proffitt, 2006; Witt, 2011). These distortions have been observed under a variety of circumstances, and appear to persist in both perception (Vishton et al., 2007) and memory (Clement et al., 2017; Davoli et al., 2012; Thomas et al., 2013). However, it is unclear whether these distortions persist as observers move to new viewpoints. On one hand, action-specific distortions may persist in visual perception, even after observers have moved to a new viewpoint. Alternatively, action-specific distortions may no longer be observed once observers move to a new viewpoint. To distinguish between these two possibilities, the present study assessed whether action-specific distortions persist across changes in viewpoint. Participants viewed an object that was projected onto a table, then reached for it with their index finger or a reach-extending tool. After reaching for the object, participants remained stationary or moved to a new viewpoint, then estimated the object's distance. If action-specific distortions persist across changes in viewpoint, these distortions should be observed regardless of whether participants move or remain stationary. However, if action-specific distortions do not persist across changes in viewpoint, these distortions should only be observed when participants remain stationary.

Overall, the present findings suggest that action-specific distortions do not persist across changes in viewpoint. In Experiments 1A and 1B, we replicated the effects of tool use on distance perception when participants remained stationary. In both cases, using a reach-extending tool led them to report shorter distance estimates. Thus, consistent with previous evidence, reaching with a tool appeared to compress participants' distance perception (Davoli et al., 2012; Witt & Proffitt, 2008; Witt et al., 2005). However, in Experiment 2, we found no evidence for action-specific distortions. Thus, although action-specific distortions were observed when participants remained stationary, they were eliminated when participants moved to a new viewpoint. In Experiment 3, action-specific distortions were also eliminated when participants moved and returned to their original viewpoint. Moreover, in Experiments 4A and 4B, these distortions were eliminated when participants rotated in place or took a step backward. In both cases, participants reached and estimated distance from the same viewpoint, suggesting that the present findings were not due to viewpoint dependence. Lastly, in Experiment 5, action-specific distortions were eliminated when observers simply walked in place. This suggests that the present findings were due to a form of dual-task interference, and could be observed when participants perform any motor action. Together, these findings suggest that action-specific distortions do not persist as observers move and perform other actions.

Theoretical implications

The present findings have important implications for the action-specific perception literature. As a number of studies indicate, performing actions can distort the perception of size (Wesp et al., 2004; Witt et al., 2008; Witt & Proffitt, 2005), distance (Proffitt et al., 2003; Stefanucci et al., 2005; Witt et al., 2004, 2005), and slant (Bhalla & Proffitt, 1999; Proffitt et al., 1995). Moreover, these distortions appear to persist in both perception (Vishton et al., 2007) and memory (Clement et al., 2017; Davoli et al., 2012; Thomas et al., 2013). Based on these findings, action-specific distortions appear to play a persistent role in our visual perception of the world. Nonetheless, the present findings suggest that these distortions may not be as persistent as many theoretical accounts assume. Most action-specific distortions have been studied under stationary viewing conditions. This differs from many real-world situations, in which observers are free to move and observe objects from multiple viewpoints. While the present findings suggest that action-specific distortions can be observed when observers remain stationary, these distortions are eliminated when observers move and perform other actions. Such findings challenge the assumption that physical abilities play a persistent role in visual perception.

Notably, the present findings conflict with some evidence from the action-specific perception literature. For example, Vishton et al. (2007) found that action-specific distortions can persist in perception, even after observers have completed an action. However, like many studies of action-specific perception, this study measured visual perception from a fixed viewpoint. Several studies have also found that action-specific distortions can persist in memory, even when observers move and interact with multiple objects (Clement et al., 2017; Davoli et al., 2012; Thomas et al., 2013). However, these studies differed from the present study in several important ways. First, while participants in the present study viewed objects that were projected onto a table, participants in the previous studies often viewed real-world objects. It is possible that when observers interact with real-world objects, action-specific distortions may be more persistent across changes in viewpoint. Indeed, there is evidence that real-world objects are more memorable than images of objects (Snow, Skiba, Coleman, & Berryhill, 2014). Second, while participants in the present study interacted with individual objects, participants in the previous studies often interacted with a group of objects. It is possible that when observers interact with multiple objects, action-specific distortions may become integrated across changes in viewpoint. Lastly, while the present study assessed participants' distance perception, the previous studies assessed participants' spatial memory. It is possible that once action-specific distortions have entered memory, these distortions may become less sensitive to interference from other actions. In line with this suggestion, some studies have found that action-specific distortions are more persistent in memory (e.g., Cooper et al., 2012).

Although the present findings conflict with evidence from the action-specific perception literature, these findings are consistent with recent challenges to the action-specific account of perception. For example, Firestone (2013) has argued that while action-specific distortions should be subjectively noticeable in many real-world situations, most observers fail to notice any changes in their perception. In line with this suggestion, a growing number of studies have failed to replicate many action-specific distortions of size (Cooper et al., 2012), distance (Woods et al., 2009), and slant (Durgin et al., 2009; Shaffer & Flint, 2011). Although such findings are often attributed to demand characteristics or other response biases (e.g., Firestone, 2013; Firestone & Scholl, 2016), the present findings provide another possible explanation for these findings. If action-specific distortions are sensitive to interference from other actions, these distortions may be eliminated when observers move and perform other actions. Thus, action-specific distortions may not be subjectively noticeable because observers are free to move and observe objects from new viewpoints.

Importantly, the present findings are also consistent with evidence from the ecological perception literature. As a number of studies indicate, changes in observers' physical abilities can influence the perceived affordances for sitting (Mark et al., 1990) and stair climbing (Mark, 1987; Warren, 1984). For example, when observers wear wooden blocks that extend the length of their legs, they are less accurate at judging affordances for sitting and climbing. However, when participants are free to observe these surfaces from new viewpoints, they become more accurate at judging these affordances (Mark, 1987; Mark et al., 1990). Similarly, participants often underestimate their ability to cross deep gaps in the ground. However, when participants are free to observe these gaps from new viewpoints, they become more accurate at judging their ability to cross these gaps (Jiang & Mark, 1994; Mark et al., 1999). These findings suggest that observers can more accurately perceive affordances when they are free to move and observe objects from new viewpoints. Based on the present findings, these effects may be due to interference from other actions. In this case, moving and performing other actions may eliminate any distortions of visual perception, allowing observers to more accurately perceive affordances for sitting, climbing, and other actions.

Possible mechanisms

The present findings suggest that action-specific distortions are eliminated when observers move and perform other actions. These findings are consistent with previous evidence that has been attributed to changes in observers' intentions. According to the action-specific account of perception, action-specific distortions are often specific to observers' intentions, with physical abilities only distorting perception when observers intend to perform an action, such as throwing a ball (Witt et al., 2004, 2010) or reaching with a tool (Witt et al., 2005). Moreover, simply intending to reach for an object can distort visual perception, even when observers do not physically interact with the object (Davoli et al., 2012; Vishton et al., 2007; Witt & Proffitt, 2008; see also Davoli & Abrams, 2009). Such findings suggest that action-specific distortions may be continuously updated as a function of observers' intentions. Indeed, when observers' intentions abruptly change, these distortions are no longer observed (Witt et al., 2010). Based on the present findings, these effects may be due to a form of dual-task interference. In previous studies that have manipulated observers' intentions, participants intend to perform an action, but are asked to perform another action when estimating size or distance. In such cases, action-specific distortions are not observed when this action differs from the intended action. In the present study, action-specific distortions were eliminated when participants performed any motor action. This suggests that these distortions may be sensitive to interference from other actions, particularly when these actions differ from the intended action.

The present findings are also consistent with previous evidence that has been attributed to motor interference. According to the motor planning literature, intending to perform an action generates an internal motor simulation of the intended action (e.g., Jeannerod, 2001). Proponents of the action-specific account of perception suggest that these simulations are responsible for many action-specific distortions. Indeed, motor simulations are thought to account for many effects of intended actions on visual perception (Davoli et al., 2012; Vishton et al., 2007; Witt & Proffitt, 2008; see also Davoli & Abrams, 2009). However, performing other actions is thought to interfere with these simulations. For example, when observers grasp another object during an intended action, action-specific distortions are no longer observed (Witt & Proffitt, 2008). Based on the present findings, these effects may be due to a broader form of dual-task interference. In previous studies that have examined motor interference, participants intend to perform an action, but are asked to perform another action during this intended action. In such cases, action-specific distortions are not observed when this action is performed with the same hand as the intended action. In the present study, action-specific distortions were eliminated when participants performed any motor action, not just those that share characteristics with the intended action. Future work should examine whether these findings are specific to performing motor actions, or whether they can be observed when observers perform a non-motor task.

Although we have suggested that observers' physical abilities directly influenced visual perception, some researchers have attributed these findings to differences in perceptual-motor calibration (e.g., Pan, Coats, & Bingham, 2014). As a number of studies indicate, changing the visual and sensorimotor feedback associated with an action can influence how that action is performed (Durgin & Pelah, 1999; Durgin et al., 2005; Rieser, Pick, Ashmead, & Garing, 1995). For example, observers often underestimate distance when reaching for a target under restricted viewing conditions. However, providing additional visual and sensorimotor feedback from reaching can progressively reduce these distortions (Bingham & Pagano, 1998). In the present study, participants received additional visual and sensorimotor feedback when they reached with the baton. This feedback may have altered the perceptual-motor calibration associated with reaching, leading participants to report shorter distance estimates. If this is the case, observers' physical abilities may not directly influence visual perception. Instead, performing an action may simply alter the perceptual-motor calibration associated with that action. Firestone (2013) has made a similar argument regarding the effects of effort on distance perception. Although the present study was not designed to test this possibility, future research should address the possible role of perceptual-motor calibration in the present findings.

If the present findings are due to differences in perceptual-motor calibration, it is also possible that the elimination of action-specific distortions may be due to a similar mechanism. In the present study, participants received additional visual and sensorimotor feedback when they moved to a new viewpoint. This feedback may have also altered the perceptual-motor calibration associated with reaching, thus eliminating any action-specific distortions. Although this explanation is largely consistent with the present findings, it is unlikely to account for the results of Experiment 5. In our first four experiments, participants' movement provided additional visual and sensorimotor feedback that could have altered the perceptual-motor calibration associated with reaching. However, walking in place does not provide any visual feedback. Moreover, a number of studies suggest that the calibration of one action does not influence the calibration of anatomically or functionally distinct actions (Durgin & Pelah, 1999; Durgin et al., 2005; Rieser et al., 1995). Thus, although walking in place may have altered the perceptual-motor calibration associated with walking, it is unlikely that this type of movement could have altered the sensory-motor calibration associated with reaching. Together, these findings suggest that the elimination of action-specific distortions was not due to differences in perceptual-motor calibration. Instead, these findings are consistent with a form of dual-task interference.

Although the present findings appear to be due to dual-task interference, there are also several alternative explanations for these findings. First, it is possible that action-specific distortions simply decayed over time. When participants remained stationary, they always estimated distance immediately after reaching. However, when participants moved to a new viewpoint, several seconds elapsed between reaching and estimating distance. Thus, action-specific distortions may have passively decayed as participants moved and performed other actions. Although this explanation is possible, we consider it unlikely to account for the present findings. In the present study, participants' movement lasted for only several seconds. However, there is evidence that action-specific distortions can persist in perception for up to several minutes (Vishton et al., 2007). The duration of participants' movement also varied across experiments, with the shortest duration associated with taking a step backward. If action-specific distortions passively decayed over time, these distortions should have been greatest in this condition. However, action-specific distortions were eliminated in each of our experiments, suggesting that this was not the case. Together, these findings suggest that action-specific distortions did not simply decay over time.

In addition to passive decay, it is possible that moving and performing other actions produced other action-specific distortions. As a number of studies indicate, the effort associated with walking or throwing can distort observers' distance perception, with increasing effort leading to increased perception of distance (Proffitt et al., 2003; Stefanucci et al., 2005; Witt et al., 2004, 2010). In the present study, moving to a new viewpoint required more effort than remaining stationary. Thus, the effort associated with walking may have reduced any action-specific distortions associated with reaching. Again, we consider this explanation unlikely to account for the present findings. In the present study, participants performed relatively simple actions, such as taking a step backward. However, previous studies have manipulated effort using more difficult tasks, such as walking on a treadmill for several minutes (Proffitt et al., 2003; Witt et al., 2004, 2010). The amount of effort also varied across experiments, with the greatest amount of effort associated with moving completely around the table. If moving and performing other actions produced other action-specific distortions, these distortions should have been greatest in this condition. However, action-specific distortions were eliminated in each of our experiments, suggesting that this was not the case. Thus, the present findings do not appear to be due to physical effort.

Lastly, it is possible that moving to new viewpoints reduced the experimental demands of our task. Many opponents of the action-specific account of perception suggest that action-specific distortions are due to demand characteristics or other response biases (e.g., Firestone, 2013; Firestone & Scholl, 2016). In line with this suggestion, a growing number of studies have failed to observe action-specific distortions when observers are unaware of the experimental hypotheses (Cooper et al., 2012; Durgin et al., 2009; Shaffer & Flint, 2011; Woods et al., 2009). If action-specific distortions were due to demand characteristics, moving and performing other actions may have reduced participants' awareness of the experimental hypotheses. This, in turn, may have reduced any action-specific distortions. Again, we consider this explanation unlikely to account for the present findings. In each of our experiments, fewer than five participants correctly guessed that the baton would influence their distance estimates. Moreover, no participants guessed that the baton would influence their distance estimates when they remained stationary. If the present findings were due to demand characteristics, the rate of guessing should have been higher in this condition. Thus, the present findings do not appear to be due to demand characteristics.

Conclusions

In summary, we found that action-specific distortions do not persist as observers move to new viewpoints. When participants remained stationary, using a reach-extending tool led them to report shorter distance estimates. However, when participants moved to a new viewpoint, these distortions were eliminated. Similar effects were observed when participants produced different types of movement, including when participants rotated in place, moved to a new location, or simply walked in place. Together, these findings suggest that action-specific distortions are eliminated when observers move and perform other actions. Such findings challenge the assumption that physical abilities play a persistent role in visual perception, and suggest one possible explanation for why action-specific distortions are not subjectively noticeable. Specifically, because observers are free to move and observe objects from new viewpoints, action-specific distortions may not be observed in many real-world situations.

Open Practices Statement The materials, analyses, and data from all of our experiments are available on the Open Science Framework (https://osf.io/ca8jf/). None of our experiments were preregistered.

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