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OBSERVATION

How Far Away Is That? It Depends on You: Perception Accounts for the Abilities of Others

Richard A. Abrams and Blaire J. Weidler
Washington University

Perception is believed to scale the world to reflect one's own capabilities for action—objects that are more effortful to obtain are perceived as further away. Somewhat surprisingly, perception is also influenced by observing another person attempt an action, even though others cannot directly alter one's own capabilities. It is unknown, however, whether the effects of observation reflect a simulation of one acting as if from the perspective of the actor, or whether they reflect simulation of the potential effects of the actor on the environment, but from the observer's own point of view. In 2 experiments, we had an actor and an observer view a scene from opposing viewpoints. Enhancement of the actor's capabilities to reach a target object caused the target to appear further from the observer. Thus, in addition to indexing one's own capabilities, the perceptual system also scales the world to account for the potential effects of others.

Keywords: action-specific perception, distance perception, vision, action

The action-specific account of perception posits that perception scales the world to reflect an individual's capabilities for action (e.g., Proffitt, 2006; Witt, 2011a). According to this view, the perceptual system indexes the extent to which certain objects or actions are attainable. For example, objects that are out of reach look closer when a person wields a reach-extending tool (e.g., Davoli, Brockmole, & Witt, 2012; Witt, 2011b; Witt, Proffitt, & Epstein, 2005). And hills look steeper when a person is encumbered by a heavy backpack (Bhalla & Proffitt, 1999). The scaling of spatial layout by the perceptual system is thought to be adaptive because it conveys the likelihood that an attempted action might succeed.

A result that challenges these ideas is that action capabilities also affect an observer with no intention to act. For example, Bloesch, Davoli, Roth, Brockmole, and Abrams (2012) had participants observe actors reaching for a nearby object. When the actor wielded a reach-extending tool, the object was judged by the observer to be closer (similar results were reported by Costantini, Ambrosini, Sinigaglia, & Gallese, 2011). Similarly, Witt, Sugovic, and Taylor (2012) had observers estimate the speed of a moving ball in a video game while an actor attempted to block the ball with a (virtual) paddle. When the actor's task was facilitated by a larger paddle, the observers (as well as the actors) judged the ball to be moving more slowly. The researchers account for these results by suggesting that the observer engages in a simulation of the observed behavior, and hence imagines the scene as if in the position of the actor—an interpretation consistent with the action-specific account (Witt, South, & Sugovic, 2014).

However, in all previous research on perceptual effects of observed actions, the observer and actor shared the same viewpoint—they sat side-by-side. Hence, an object that was more easily attainable by the actor (because of the possession of a reach-extending tool, or a larger paddle) would also be more easily attainable by the adjacent observer. Thus, the findings are consistent with two very different possibilities: After engaging in simulation to evaluate the effects of the action, the observer (a) assesses the scene from the viewpoint of the actor as if the observer was in the actor's position; or (b) evaluates the effect of the actor's capabilities on the environment, and then assesses the scene from his or her own location. Because the observer in past research was always adjacent to the actor, these two possibilities cannot be disentangled.

In order to distinguish between the possibilities just identified, in the present experiments, we studied observed tool use when an actor and observer each viewed a target object from opposing locations. In that situation, enhancement of the actor's capabilities to interact with a target (by providing a tool) would have different effects on the observer's perceptions depending on which explanation is correct. If the observer simulates the actions from the point of view of the actor, then enhancing the actor's capabilities should cause the target to appear closer (as it would if the observer themselves used the tool; e.g., Witt et al., 2005). Alternatively, if the observer simulates the actor's tool-enhanced capabilities, but then assesses the scene from his or her own location, then the target would appear farther away. To anticipate the outcome, we found that a tool that allowed the actor to reach the target caused the observer to perceive the target to be *farther* away, showing that perception scales the environment based not only on one's own capabilities but also taking into account the capabilities of the others who are present.

Richard A. Abrams and Blaire J. Weidler, Department of Psychology, Washington University.

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Correspondence concerning this article should be addressed to Richard A. Abrams, Department of Psychology, Washington University, 1 Brookings Drive, St. Louis, MO 63130. E-mail: rabrams@wustl.edu

Experiment 1

Method

We had participants judge distances using a perceptual matching task modeled after those used by Witt (2011b). Twenty-four naïve participants viewed stimuli that were projected onto a 200 × 150-cm screen on the floor. The setup for the experiment is shown in Figure 1. The participant sat on a chair on one side of the screen with a naïve experimenter seated on the opposite side. On each trial, a yellow target circle and a cyan reference circle (2.5 cm diameter) appeared, aligned along the axis between the experimenter and participant. The experimenter then pointed to the target circle either by hand (no-tool condition) or with a 65-cm long stylus (tool condition). The target circle was always out of the experimenter's reach without the stylus, but within reach with the stylus. When pointing with the stylus, the experimenter tapped the target circle. One second after the circles' appearance, two white response circles appeared, aligned perpendicular to the target-circle/reference-circle axis. The participant was instructed to use a keypad to adjust the lateral distance between the response circles (oriented vertically in Figure 1) until the separation between the white response circles appeared equal to that between the two colored circles (i.e., the target and reference circles). The two response circles were always equidistant from the target-circle/reference-circle axis. When the participant was satisfied with the circle locations, they pressed a key to record the response and advance to the next trial.

The target circle could appear at one of 10 locations, producing separations between target and reference circle ranging from 19.7 to 66.7 cm (locations were evenly spaced within that range). The participant could increase and decrease the distance between response circles in steps of 2.7 cm within the range of 0 to 152 cm. When they first appeared on each trial, the separation between response circles was randomly selected from within the range between 15 and 75 cm.

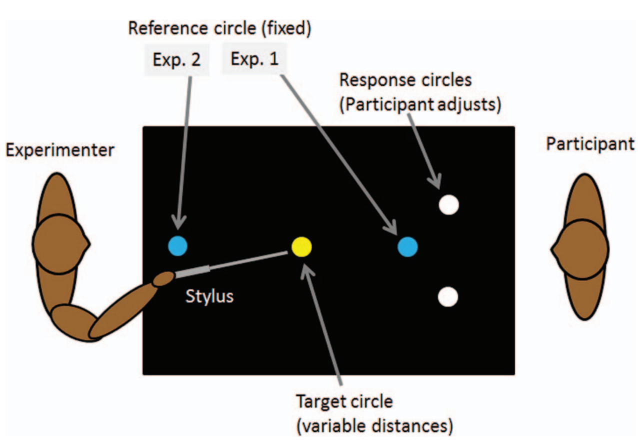

Figure 1. Setup for Experiments 1 and 2. The only difference between experiments involves the location of the reference circle; within each experiment, its location was fixed. The target circle could appear at one of 10 locations. The experimenter pointed to the target circle, sometimes with a stylus and sometimes without. The participant adjusted the separation between the response circles to provide their response. See text for additional explanation. See the online article for the color version of this figure.

After a block of practice trials, participants served in eight blocks, each of which contained one trial at each of the 10 target distances, in a random order. The tool condition (tool or no-tool) was constant for the first four blocks and then switched to the other condition for the final four blocks. Condition order was counterbalanced across subjects.

Results

Participants were asked to judge the distance between target and reference circles by adjusting the separation between the response circles. Their responses are shown in Table 1 for each of the 10 actual distances, collapsed over the two tool conditions. The perceived distance depended heavily on the actual distance, increasing as the actual distance increased, $F(9, 207) = 536.0$, $p < .001$, $\eta_p^2 = .96$. To examine the effect of tool use, we computed the *difference* in distance judgments between the tool and no-tool conditions (the inferential statistics reported are based on the distance judgments, not the computed differences). These values are plotted in Figure 2 for each of the 10 target locations. Because the reference circle was fixed and closer to the participant, increases in the perceived distance between circles correspond to an increased perceived distance to the target circle. Importantly, when the actor pointed with the stylus (and hence could reach the target circle), participants judged the target circle to be on average 1.7 cm further away than when the actor pointed by hand, $F(1, 23) = 4.6$, $p = .04$, $\eta_p^2 = .17$. In addition, the effect of tool was larger for the greater distances, resulting in an interaction between tool use and distance, $F(9, 207) = 2.1$, $p = .03$, $\eta_p^2 = .09$ (an effect similar to that which has been reported by others; e.g., Bloesch et al., 2012; Davoli et al., 2012).

Discussion

In the present experiment, participants perceived a target object to be further away when the experimenter, seated on the opposite side of the display, was able to reach the target with a stylus. This conclusion follows from the greater separation between the response circles when the experimenter pointed to the target circle with the stylus compared with pointing with only their hand. Because the reference circle was fixed in place and closer to the participant, any increase in the perceived distance to the target would be accompanied by an increased perceived distance between the reference circle and the target, as observed. Thus, these results suggest that people scale the world to account for the capabilities of others.

Despite the clear results, an alternative interpretation is possible. It could be that the increased perceived distance between target and reference circle reflects some other nonspecific influence of the experimenter's wielding of a stylus. For example, perhaps when the experimenter used a stylus, distances between any two arbitrary objects in the display would be perceived to expand. Indeed, there is some evidence suggesting that interaction can lead to a change in the spatial extent of the environment in which the interaction occurred. Thomas, Davoli, and Brockmole (2013) observed compression of a spatial layout after participants were permitted to interact with objects in the environment. Although in an opposite direction, the result leaves open the possibility that a generalized change in spatial scale could underlie the effects reported in Experiment 1. In order to rule out that possibility, we conducted Experiment 2

Table 1
Actual Distance and Mean Perceived Distance Between Target and Reference Circles From Experiments 1 and 2

Actual distance between target and reference circles (cm)	Perceived distance between target and reference circles in Experiment 1 (cm)	Perceived distance between target and reference circles in Experiment 2 (cm)
19.7	24.8 (.93)	23.7 (.61)
24.9	31.5 (1.06)	29.9 (.63)
30.1	38.5 (1.38)	35.8 (.74)
35.3	44.3 (1.42)	41.7 (.77)
40.6	50.6 (1.47)	46.7 (.84)
45.8	57.1 (1.99)	52.5 (.85)
51	63.1 (2.17)	58.9 (1.18)
56.2	68.3 (2.28)	65.7 (1.17)
61.5	73.9 (2.54)	73.6 (1.26)
66.7	79.7 (2.78)	79.0 (1.44)

Note. Standard errors are in parentheses.

Experiment 2

In Experiment 1, as in many other experiments involving tool use, a critical assumption is that the pointing behavior influenced only attributes of the element that was pointed to, and not some nonspecific expansion or compression of space that would affect judgments of targets as well as nontargets. For the situation studied in Experiment 1, we have assumed that only the perceived target location was affected by pointing with the stylus, but we cannot logically eliminate the alternative possibility that any judged distance between elements in the display might have exhibited expansion in the conditions that involved a stylus. To rule out that possibility, we repeated Experiment 1 with one minor but critical change: We moved the reference circle to the opposite side of the display (see Figure 1). Here, the target circle, to which the experimenter pointed, was closest to the participant instead of furthest from the participant as it had been in Experiment 1. In this case, if (experimenter) pointing with a stylus causes the pointed-to circle to appear (to the participant) further away, and closer to the experimenter who wields the tool, as we have assumed, then that should result in a *reduction* in the perceived distance between circles—a response pattern opposite to that observed in Experiment 1. Such a result would rule out generalized spatial expansion as an explanation for the earlier experiment. However, if the results of Experiment 1 stem instead from some nonspecific expansion of space caused by stylus use, then the same pattern of responses (increased separation when the stylus is used) should be observed here.

Method

A new group of 24 participants served in the experiment, which was identical to Experiment 1 in all ways except one: Here, the cyan-colored reference circle was located closer to the experimenter, as seen in Figure 1. The distances between target and

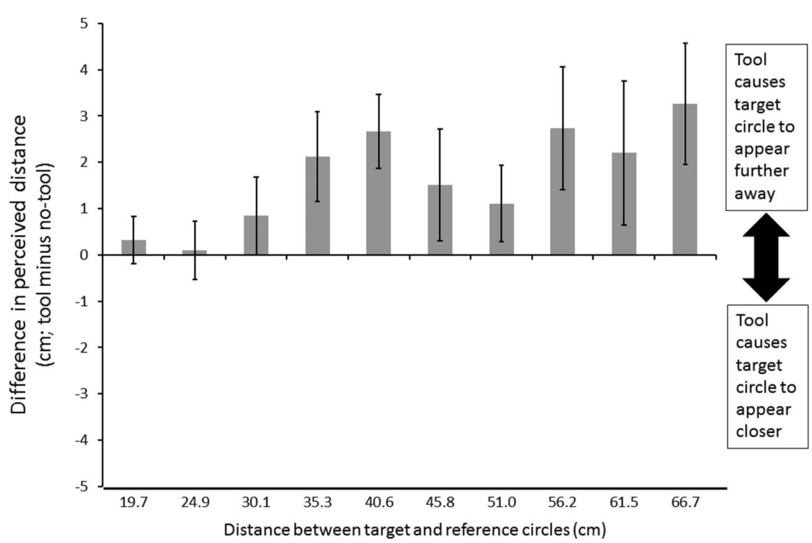

Figure 2. Results from Experiment 1. The bars plot the mean difference in perceived distance between the two tool conditions (tool minus no-tool; error bars show standard errors). Positive difference values indicate distances at which use of the tool caused the perceived separation between circles to be greater, presumably because the target circle appeared further away.

reference circles were the same as before; the experimenter pointed to the target circle as before; and the participant judged the separation between the two colored circles as before.

Results

The mean distances between response circles are shown in Table 1 for each of the 10 target locations, averaged over the two tool conditions. The judged separation between target and reference circles depended heavily on the target location, increasing with increasing distance between circles, $F(9, 207) = 1117.9$, $p < .001$, $\eta_p^2 = .98$. The bars in Figure 3 show the difference in distance judgments between the tool and no-tool conditions, with negative values indicating decreased distances between circles, and hence an increased distance to the target circle. Participants judged the target circle to be on average 1.24 cm further away when the actor pointed with the stylus than when the actor pointed by hand, $F(1, 23) = 9.4$, $p < .01$, $\eta_p^2 = .29$. There was no interaction between distance and tool condition, $F(9, 207) = 1.8$, $p = .08$, but the trend matched that from Experiment 1, with a larger effect of tool condition when the target and reference circles were further apart.

Discussion

In this experiment, as in Experiment 1, participants perceived the target circle to be further away when the experimenter was able to reach the target with a stylus, compared with when the experimenter pointed to the (unreachable) target by hand. Importantly, in the present experiment, increased distance to the target was inferred by a judged decreased separation between target and reference circles because here, unlike in Experiment 1, the reference circle was further from the participant than the test circle. Thus, the result replicates the findings from Experiment 1 and also rules out the possibility that the earlier results were caused by a general expansion of the spatial layout. Such a possibility would have yielded increased separation judgments here, too, which is in opposition to the effect that was observed.

General Discussion

Numerous empirical results suggest that the perceptual system scales the world to reflect one's own capabilities (e.g., Proffitt, 2006; Witt, 2011a). We have shown here, for the first time, that the perceptual system also scales the world to reflect the capabilities of others: A target that is more easily attainable by another individual is seen as closer to oneself when the actor is adjacent (Bloesch et al., 2012), but seen as further away when the actor is opposite (the present results). Such an effect is highly adaptive: Consider assessing the likelihood of successfully reaching a piece of food that was also within reach of an adversary. Certainly, the adversary's capabilities would be relevant. And apparently, as we have shown, those capabilities are considered by the perceptual system.

The present results help to distinguish between the two alternative explanations of previous findings that were introduced earlier. According to both accounts, it is believed that observers simulate the actions of a nearby actor in order to account for the effects of those actions. Then, according to one explanation, observers assess the effects of the action on the environment from the adopted viewpoint of the actor. According to the other explanation, observers account for the actor's effect on the environment, but do so from their own viewpoint. This latter possibility would presumably require a spatial transformation from the viewpoint of the actor to that of the observer if those viewpoints differed. Because actor and observer were always adjacent to one another in the earlier studies (e.g., Bloesch et al., 2012; Witt et al., 2014), it was not possible to distinguish between the alternatives, but we can do so now. In particular, observers assess the actor's impact on the environment from their own viewpoint. This rules out the possibility that observers simply put themselves in the place of the actor and simulate the actor's actions from the actor's viewpoint.

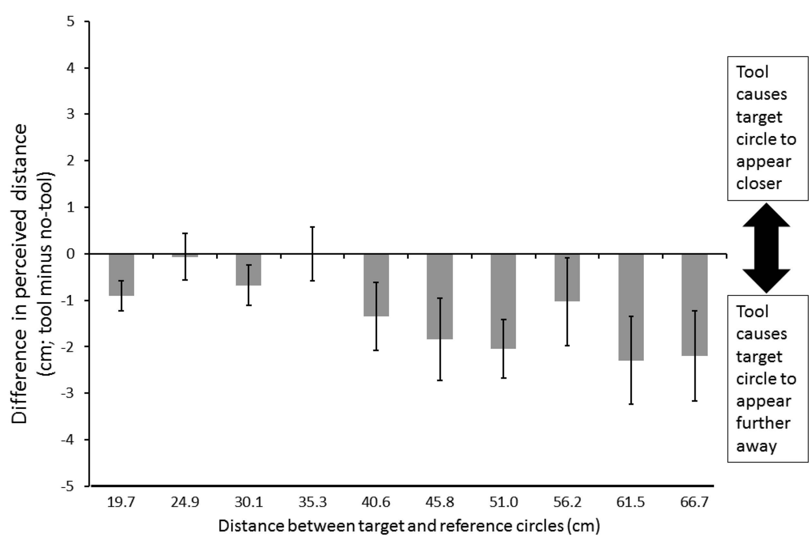

Figure 3. Results from Experiment 2. The bars plot the mean difference in perceived distance between the two tool conditions (tool minus no-tool; error bars show standard errors). Negative difference values indicate distances at which use of the tool caused the perceived separation between circles to be smaller, presumably because the target circle appeared further away.

Some aspects of our results are consistent with recent conclusions of Linkenauger, Leyrer, Bülthoff, and Mohler (2013), who studied changes in the perceived size of objects with changes in the apparent size of the participant's hand. Those authors suggested that information in the optic array is transformed into distance by use of a "perceptual ruler" or scale (also see Proffitt & Linkenauger, 2013). Changes in one's capabilities, such as when a tool extends one's reach, alters (in that case lengthens) the perceptual ruler. According to this view, a longer ruler would be expected to yield increasing differences as target distance increases. Consistent with that explanation, in Experiment 1 (and marginally in Experiment 2), the effect of tool use increased with increasing target distance. Nevertheless, in Experiment 1 (but not in Experiment 2), the increasing tool effect actually accompanied a *decreasing* distance between the target and the actor because the reference circle there was closer to the observer than was the target circle (and because the actor and observer viewed the scene from opposite viewpoints; see Figure 1). Such a result would seem to rule out a simulation by the observer as if in the actor's position, followed by a viewpoint transformation, because the simulation would be expected to yield a decreasing effect of tool as the distance between target and observer increased (because the distance between target and actor would be decreasing). One possibility, consistent with the present results, is that the origin of the perceptual ruler was anchored not to the actor, but instead to the reference circle. More study will be needed to answer the question.

The present experiments are also related to those reported by Doerrfeld, Sebanz, and Shiffrar (2012), who studied perceived weight, not spatial extent. They had participants estimate the weight of a basket of golf balls prior to lifting it. The weight estimate was affected by the presence and apparent physical well-being of a cofactor, who would also help with the lifting, showing that the participants accounted for the capabilities of another. But it is important to note that in that study, the critical weight judgments were made prior to any lifting of the basket—and hence they do not reflect differences in actual perceived weight (because weight cannot be perceived by looking)—only differences in apparent weight.[1]

In summary, the perceptual system scales the world by combining information in the optic array with other information such as one's metabolic state and physical encumbrances (e.g., Bhalla & Proffitt, 1999), access to tools (e.g., Witt et al., 2005), the desirability of the target (e.g., Balcetis & Dunning, 2010), and also, as shown here, the perceived capabilities of others to alter the environment.

[1] Indeed, in one experiment in Doerrfeld et al. (2012), weight judgments after lifting depended on the presence of a coactor. However, the authors hypothesized that those judgments may have been influenced by the fact that participants repeatedly lifted weights over many trials, and participants acting alone may have become fatigued. To address that possibility, three other experiments contained only a single trial. In those experiments, judgments after lifting were unaffected by the coactor.

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