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BRIEF REPORTS

Implied body action directs spatial attention

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Research confirms that the body influences perception, but little is known about the embodiment of attention. We investigated whether the implied actions of others direct spatial attention, using a lateralized covert-orienting task with nonpredictive central cues depicting static, right/left-facing bodies poised in midaction. Validity effects (decreased response times for validly compared with invalidly cued trials) indicated orienting in the direction of the implied action. In Experiment 1, we compared action (running, throwing) with nonaction (standing) cues. Only the action cues produced validity effects, suggesting that implied action directs attention. The action cues produced faster responses overall, suggesting that action cues prime motor responses. In Experiment 2, we determined whether action cues shifted attention in a specific direction rather than to a general side of space: Two cues had similar action speed and motor effort but differed in implied direction (jumping, vertical; throwing, horizontal). Validity effects were found only for the throw cues for which the implied motion direction was consistent with lateralized target locations. In Experiment 3, we compared block-like stimuli to the throwing action stimuli to examine whether lower level perceptual information could account for the attention effects alone. Validity effects were found only for the human-action stimuli. Overall, the results suggest that predictive simulations of action shift attention in action-consistent directions.

Traditionally, spatial attention has been viewed as a cognitive faculty that is influenced primarily by the location of objects within the visual environment (Posner & Cohen, 1984). Scientists now recognize that perception and cognition are intimately connected with our bodies and how we use them (Barsalou, 2003; Witt, Proffitt, & Epstein, 2005). Less is known about how embodiment affects attention (Tipper, Howard, & Houghton, 1999). Embodied processing should direct attention to the consequences of human action, because people in our environment often demand immediate responses.

Our own bodies influence spatial attention. Hand position facilitates target detection in the visual space around the hand (Reed, Grubb, & Steele, 2006; Schendel & Robertson, 2004). One's trunk direction can bias shifts of visual attention (Grubb & Reed, 2002). However, other people's actions are also important cues for spatial attention. They provide information about others' intentions and future actions (Loula, Prasad, Harber, & Shiffrar, 2005), as well as cues to appropriate real-time responses.

Postures and implied actions provide important cues for shifting attention, enabling anticipatory responses to action outcomes. One such implied action cue is eye gaze. In several studies (Friesen & Kingstone, 1998; Kingstone, Tipper, Ristic, & Ngan, 2004; Langton, Watt, & Bruce, 2000), participants viewed static face images with the eyes directed to one side; they responded faster to targets consistent with gaze direction. Other types of socially relevant actions can direct attention toward future events of interest. Langton and Bruce (2000) used a covert attention paradigm in which the central cue depicted a person pointing his hand; participants responded more quickly to targets consistent with the pointed direction. Nonetheless, not all body postures affect attention. When static images of left- and right-facing heads and trunks were used as cues, the head cues and the trunk-plus-head cues shifted attention, but the trunk cues alone did not (Hietanen, 2002). Perhaps

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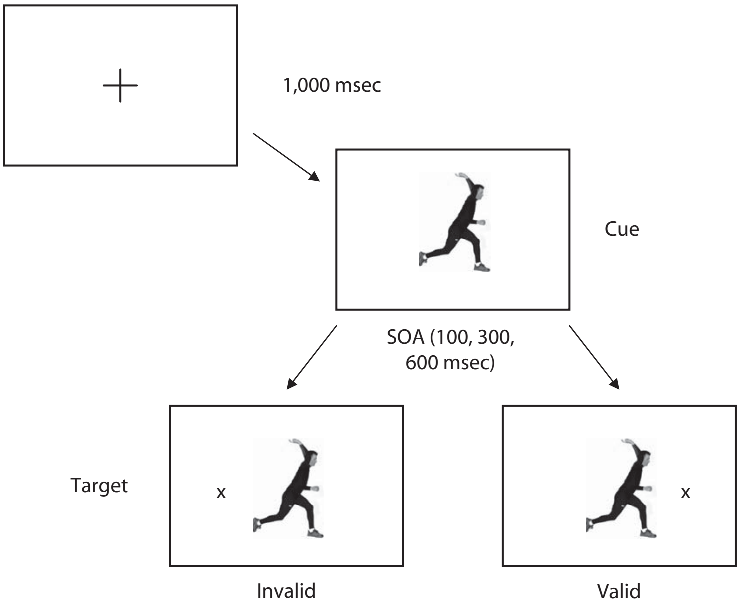

Figure 1. Illustration of the experimental procedure: Nonpredictive covert attention paradigm with a central cue. (SOA: stimulus onset asynchrony)

viewing another person's trunk direction alone did not provide enough information about where impending events were to occur. These studies suggest that the implied direction of an upcoming action indicated by gaze, head turn, and pointing may be critical for shifting attention.

We investigate whether implied directional action shifts spatial attention, and if so, what components of the action cue are critical. For objects moving in predictable trajectories, we often perform mental simulations to predict their motion (Nijhawan, 2008). However, bodily actions are perceived differently from other moving objects. When we watch people performing actions, we add implicit knowledge from our own body representation to this simulation process (Freyd, 1983; Kourtzi & Kanwisher, 2000; Wilson & Knoblich, 2005). One's own bodily experience is used to process others' actions. Body representations and motor programs help create a forward-model simulation that predicts the likely course of the action (Knoblich & Flach, 2001; Wilson, 2006). Simulations help predict the time course of the unfolding action, as well as the consequences of the action. It follows that simulation processes not only aid perception, but also guide spatial attention to action-relevant spatial locations.

To examine whether static action cues shift attention, we used a central cuing version of the nonpredictive, covert-orienting paradigm (Jonides, 1981). Static, midaction cues appeared in the center of the screen, facing to the left or right. Subsequently, a target appeared on one side of the screen; participants pressed a button indicating target detection (Figure 1). Cues were valid when the target appeared on the side that the body faced; cues were invalid when the target appeared on the opposite side. Cue direction was not predictive of target location. Thus, validity effects (decreased response times [RTs] for validly compared with invalidly cued trials) suggest that the cues' implied actions shifted attention. In Experiment 1, we compared action cues with a nonaction cue to determine whether any attention shifts could be attributed to the implied action. In Experiment 2, we compared vertical and horizontal actions to determine whether attention shifted along a directional axis consistent with the direction of the action. A throw cue, implying horizontal motion that was directed toward target locations, was compared with a jump cue, implying vertical motion orthogonal to target locations. In Experiment 3, we compared action cues with visually similar nonbody cues to confirm that the effects of the first two experiments were not driven merely by low-level visual differences between cues.

GENERAL METHOD

Participants

In Experiments 1–3, 36 University of Denver undergraduates ($M_{\text{age}} = 20.21$ years; 31 female), 23 Claremont McKenna College undergraduates ($M_{\text{age}} = 19.67$ years; 10 female), and 14 Claremont community members ($M_{\text{age}} = 19.86$ years; 11 female) participated for extra credit or were paid.

Stimuli

Experiment 1. Cues were static, color images of a human actor poised in midaction (running or throwing) or standing in a neutral pose (Figure 2). The actions were selected to be easily identifiable, to have different body configurations, and to imply clear directionality. To create images of a real person poised in midaction, we used a digital SLR camera to photograph a human actor performing actions in front of a white background. Left and right cues were mirror images of the same photograph. The cues subtended visual angles of 5.7º–6.0º high and 4.4º–4.7º wide. Cues were centered on the screen on the basis of the body's center of gravity and the target. The target "X" subtended visual angles of 1.3º high and 0.8º wide, and appeared 6.0º to the left or right of the body pose's center of gravity. The fixation subtended 0.8º of visual angle. The experi-

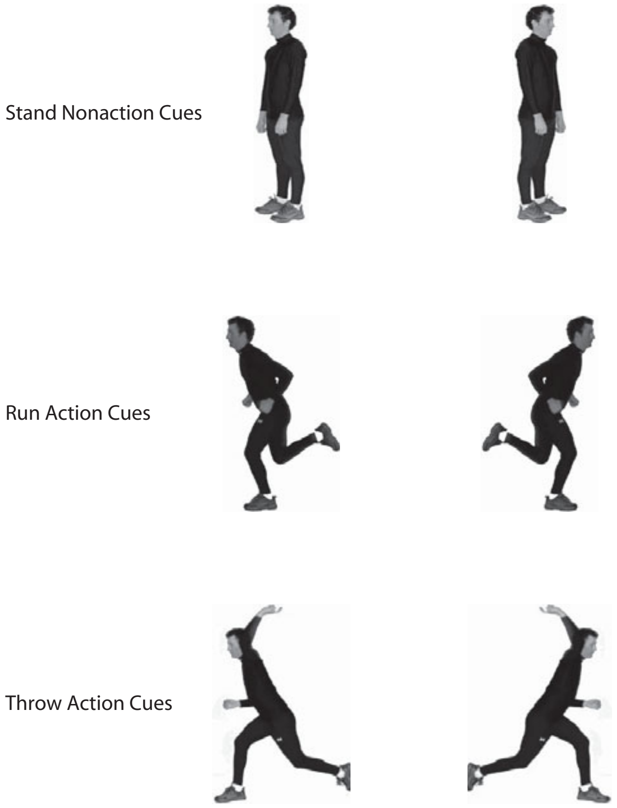

Figure 2. Cues for Experiment 1: Stand, run, and throw.

ments were conducted using E-Prime 1.1 (Psychology Software Tools, Pittsburgh, PA).

Experiment 2. Two cues were selected so that attention shifts from the implied direction of the cue would be either consistent or inconsistent with the target location. Throw cues were modified to have a line beneath the feet indicating the ground; the implied action direction was horizontal. Jump cues depicted a person at the top of a vertical jump. A line beneath the feet indicated the ground; the implied action direction was vertical (Figure 3). All of the participants readily and exclusively identified the pictures as throws and jumps in midaction. The angle of the body was more pronounced (angled more to the left or to the right) on the jump cues than on the throw cues. This comparison addressed an alternative explanation: that the stronger validity effects of the throw cues in Experiment 1 arose from their relatively more pronounced trunk angles.

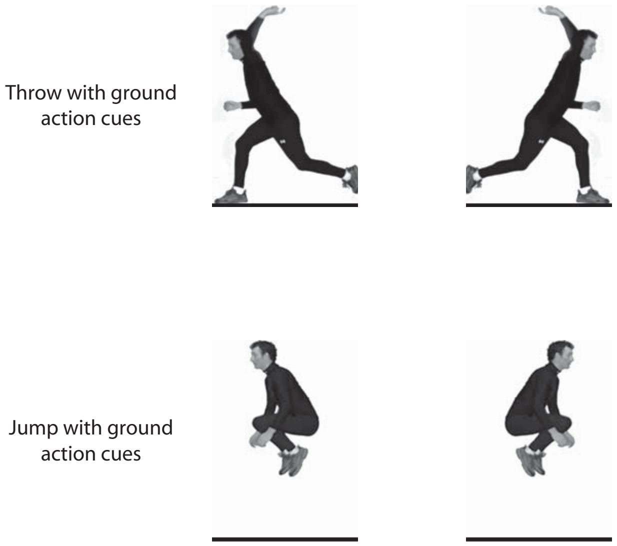

Figure 3. Cues for Experiment 2: Throw and jump actions.

Experiment 3. Block stimuli were created by placing black blocks over the throw cue image to equate the stimuli in size, angle, part proportions, and part relations (Figure 4). Block cues were compared with the previous throw cues to examine whether stimuli sharing similar visual features without the implied human action would create validity effects.

Procedure

The participants performed a covert-orienting task (Figure 1). Their heads were 60 cm from the screen. The participants were told to keep their eyes focused on the center of the screen and that cues did not predict target location. Trials began with a central fixation cross for 1,000 msec, followed by a cue in the center of the screen that remained as a target appeared either to the right or to the left of the cue; the targets appeared 100, 300, or 600 msec later and remained until either the participants responded with a keypress or 2,000 msec passed. After 10 practice trials, the participants completed nine blocks of experimental trials (432 trials; 24% catch trials). Each block had randomly presented, equiprobable combinations of action cue, stimulus onset asynchrony (SOA), cue direction, and validity.

EXPERIMENT 1

Does implied directional action, rather than trunk orientation alone, shift attention? An action-neutral cue (standing) was compared with two action cues (Figure 2: running, throwing). If trunk and head orientation alone (i.e., standing without another implied action) is sufficient to produce attention shifts, the participants should respond more quickly to validly cued than to invalidly cued targets, regardless of cue type. However, if directional implied action is necessary to shift an observer's attention, validity effects should be found for both action cues but not the nonaction cue.

Confounds in previous studies of gesture-cued attention shifts were also addressed (e.g., pointing hands may function as arrows rather than as gestures). Arrows are strong orienting cues (Kingstone, Smilek, Ristic, Friesen, & Eastwood, 2003), because their shape has inherent perceptual directionality (Palmer, 1980). The present cues were constructed so that no body part could be viewed as an arrow pointing in the same direction as the implied action; body parts always pointed in the opposite direction of the implied action. Gaze direction was equated across cues to eliminate differential gaze influences on attention shifts.

In addition, the two action cues may produce different RT and validity effects because of their different implied motion characteristics. Researchers have proposed that when viewing others performing actions, we perform internal simulations of that action (e.g., Rizzolatti, Craighero, & Fadiga, 2002; Wilson, 2001, 2006; Wilson & Knoblich, 2005), which have implications for directing spatial attention. Running an internal model of another's action permits observers to better predict the results of that action. If so,

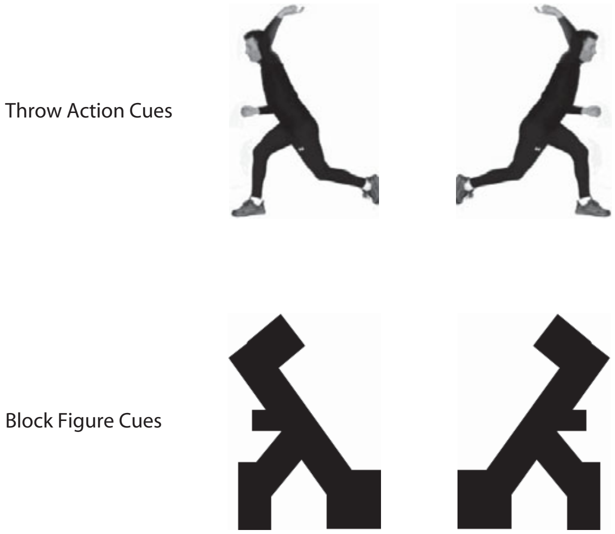

Figure 4. Cues for Experiment 3: Throw and block cues.

throw cues may produce shorter RTs and stronger validity effects than run cues, both because the target can appear in the predicted location of the action's results and because the action implied is faster and more explosive.

SOA was manipulated to investigate the time course of attention shifts from action cues. Reflexive-like attention shifts may occur at SOAs of 150 msec or less for lateralized cues (Posner & Cohen, 1984), but they also occur for centrally presented gaze and arrow cues (e.g., Kingstone et al., 2003). More cognitively mediated attention shifts tend to occur for SOAs greater than 300 msec (Posner & Cohen, 1984). If action cues produce reflexive shifts of attention, validity effects should be observed at the shorter SOAs (e.g., 100 msec). However, bodies in midaction may present more perceptual and configural complexity, requiring additional processing time prior to shifts of attention. If so, attention shifts would be expected only at the longer SOAs.

Results

In Experiments 1–3, we calculated mean RTs for each participant and condition, excluding catch trials, anticipation errors (RTs below 150 msec), and inattention errors (RTs 2.5 *SD*s above the overall mean). Two participants were excluded because of excessive errors or RT latencies.

We conducted a 2 (validity: valid, invalid) × 3 (SOA: 100, 300, 600 msec) × 3 (action: neutral, run, throw) repeated measures ANOVA. A main effect of validity [$F(1,33) = 16.08$, $p < .0001$] indicated that the nonpredictive cues produced attention shifts: The RTs for validly cued trials ($M = 323$ msec) were reliably shorter than those for the invalidly cued trials ($M = 329$ msec). The main effect of SOA [$F(2,32) = 133.57$, $p < .0001$] indicated slower responses with a 100-msec SOA ($M_{\text{RT}} = 352$ msec) than with either a 300-msec SOA ($M_{\text{RT}} = 313$ msec) [$F(1,32) = 367.09$, $p < .0001$] or a 600-msec SOA ($M_{\text{RT}} = 314$ msec) [$F(1,32) = 129.32$, $p < .0001$]. Neither the validity × SOA [$F(2,62) = 1.67$] nor the SOA × action [$F(4,128) < 1$] interaction was significant.

The main effect of action [$F(2,32) = 30.18$, $p < .0001$] showed that the participants responded more quickly to targets following action cues. The RTs for the throw cues ($M = 321$ msec) were shorter than those for the run ($M = 326$ msec) [$F(1,32) = 13.10$, $p = .001$] and neutral ($M = 332$ msec) [$F(1,32) = 86.78$, $p < .0001$] cues. The run cue RTs were shorter than those for the neutral cues [$F(1,32) = 13.11$, $p = .001$].

A significant action × validity interaction [$F(2,32) = 6.95$, $p = .002$] indicated that the action cues shifted attention to the direction implied by the action (Figure 5) but that these shifts did not vary with SOA [validity × SOA × cue interaction, $F(4,128) < 1$]. To examine how specific implied action cues influenced attention shifts, we performed a repeated measures ANOVA with validity and SOA for each cue type (neutral, run, throw) as factors. This allowed us to specifically address our hypothesis that directional body action (not just trunk orientation) is necessary for attention shifts and to examine the time course of attention.

Stand cues. A significant main effect of SOA [$F(2,64) = 123.52$, $p < .0001$] indicated that the participants responded more quickly at longer SOAs. Neither the main effect of validity [$F(1,33) < 1$] nor the SOA × validity interaction [$F(2,648) < 1$] was significant. With additional pairwise comparisons, we examined validity effects at each SOA, but no significant effects were found [all Fs$(1,32) < 1$]. Trunk orientation alone is not sufficient to shift attention.

Run cues. Significant main effects of both SOA [$F(2,64) = 74.73$, $p < .0001$] and validity [$F(1,33) = 7.35$, $p = .01$] were found, but no interaction [$F(2,64) < 1$]. Pairwise comparisons revealed validity effects only for the 600-msec SOA [$F(1,32) = 5.86$, $p = .02$; $M_{\text{RT}}(\text{invalid}) = 318$ msec, $M_{\text{RT}}(\text{valid}) = 311$ msec].

Throw cues. Significant main effects were found for SOA [$F(2,64) = 79.26$, $p < .0001$] and validity

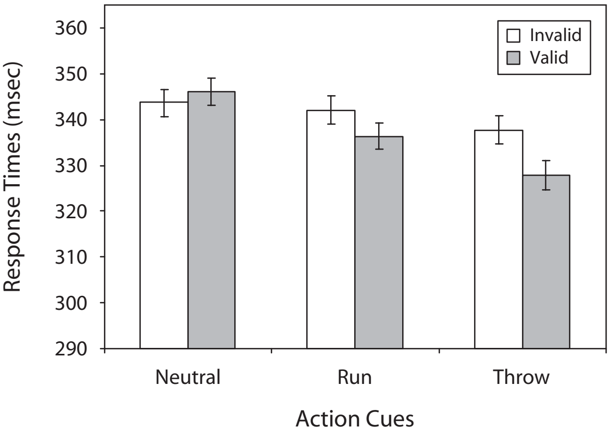

Figure 5. Experiment 1: Type of action × validity interaction. Error bars represent 95% within-subjects confidence intervals. Action cues shifted attention, but a nonaction cue did not.

[$F(1,33) = 22.54$, $p < .0001$], but there was no interaction [$F(2,64) = 1.33$]. Pairwise comparisons revealed significant validity effects at each SOA [100 msec, M_{RT}(invalid) = 350 msec, M_{RT}(valid) = 342 msec, $F(1,32) = 7.31$, $p = .011$; 300 msec, M_{RT}(invalid) = 312 msec, M_{RT}(valid) = 304 msec, $F(1,32) = 6.73$, $p = .014$; 600 msec, M_{RT}(invalid) = 315 msec, M_{RT}(valid) = 301 msec, $F(1,32) = 12.39$, $p = .001$]. The throw cues shifted attention for all SOAs.

Post hoc analyses comparing the validity effects produced by action cues showed that the throw cues produced stronger validity effects than did the run cues [$F(1,32) = 4.06$, $p = .05$], as well as shorter overall RTs [$F(1,32) = 12.32$, $p = .001$]. Although both action cues (running, throwing) produced attention shifts, the faster implied action of the throw cues appeared to increase the magnitude of the validity effect, as well as the robustness of the validity effect across SOAs.

Thus, implied action appears to shift attention. Although both the run and the throw cues shifted attention, only the throw cues produced shifts at the shortest SOA. The run cues produced attention shifts only at the longer SOAs. This discrepancy may result from relative timing differences for single events and continuous actions: A throw event is fast and ends. Attention appears to be shifted in the direction of the implied action, and faster implied actions invoke faster responses.

Nonetheless, given that both action cues in Experiment 1 depicted horizontal motions, we cannot state definitively that implied action cues shifted attention in the direction of the implied motion. In addition, other perceptual cues may have influenced the results. For example, the stronger validity effects of the throw cues may arise from their more pronounced left- or right-leaning trunk angles. To address this possibility, the action cues used in Experiment 2 were equated for head direction, body direction, and torso lean.

EXPERIMENT 2

Were the attention shifts observed in Experiment 1 influenced by the specific direction of action implied by the action cue or merely by perceptual cues (e.g., trunk angle)? If the implied action cues generate a motor simulation process, any action cue may evoke general arousal for faster responses and may direct attention to a general region of space indicated by head and body direction, regardless of that action's implied direction. Alternatively, action simulation processes may direct attention along the specific axis of the implied motion.

We selected two implied action cues that were single events comparable in execution speed but that differed in the direction of their implied motion: Throw cues depict horizontal motion, and jump cues depict vertical motion. Using the paradigm used in Experiment 1, we determined whether implied action cues direct attention in a specific direction. If motor simulation shifts attention for any action cue, validity effects and overall RTs should be similar for both cues. However, if the implied action shifts attention in an action-consistent direction, validity effects should be found only for the throw cue, because its implied horizontal motion shifts attention to the target location.

Results

One participant was excluded from the analyses for inattention errors. We conducted a repeated measures 2 (validity: valid, invalid) × 3 (SOA: 100, 300, 600 msec) × 2 (action: jump, throw) ANOVA. The RTs for validly cued trials ($M_{\mathrm{RT}} = 314.89$ msec) were shorter than those for invalidly cued trials ($M_{\mathrm{RT}} = 320.33$ msec) [$F(1,21) = 6.70$, $p = .017$]. Responses for the longer SOAs were faster than those for the short SOAs [M_{RT}(100 msec) = 342.03 msec, M_{RT}(300 msec) = 301.10 msec, M_{RT}(600 msec) = 309.70 msec] [$F(2,20) = 99.74$, $p < .0001$]. The action effect was not significant [$F(1,21) = 3.11$, $p < .10$] (throw cue, $M_{\mathrm{RT}} = 315.96$ msec; jump cue, $M_{\mathrm{RT}} = 319.26$ msec); to the extent that implied action speed influences overall RT, the implied speed for the two cues appeared comparable. Although the validity × SOA interaction was not significant [$F(1,20) = 2.80$], the SOA × action interaction was significant [$F(2,20) = 11.32$, $p < .001$]. The RTs for both cues decreased between the 100- and 300-msec SOAs. Only the jump cue RTs increased at the 600-msec SOA. The three-way interaction was not significant [$F(2,20) < 1$].

Importantly, the significant action × validity interaction [$F(1,21) = 4.60$, $p = .04$] suggested that the implied direction of action influenced attention shifts (Figure 6). To determine how each action directed attention, we conducted post hoc validity × SOA ANOVAs and individual validity effect analyses for each action and SOA.

Jump cues. A significant main effect of SOA for the jump cues [$F(2,20) = 44.31$, $p < .0001$] indicated longer

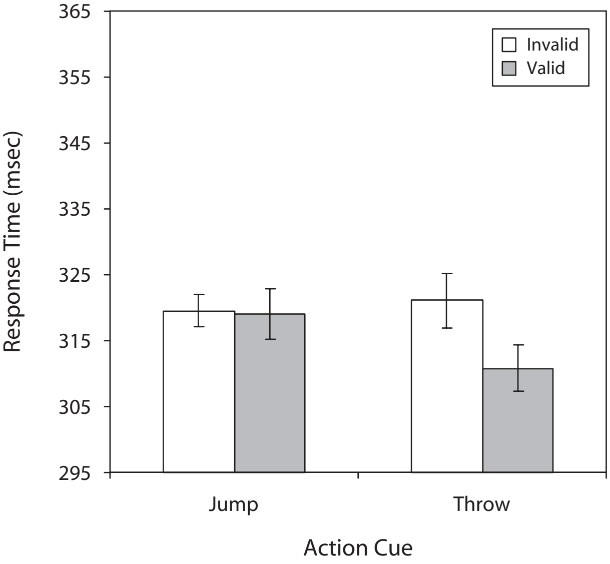

Figure 6. Experiment 2: Direction of action × validity interaction. Error bars represent 95% within-subjects confidence intervals. Only the throw cue produced a validity effect. Implied action cues appear to shift attention along a specific axis of motion, rather than toward the general side of space to which a body faces.

RTs at the 100-msec SOA than at the 300- and 600-msec SOAs. There was no effect for validity [$F(1,21) < 1$] and no interaction [$F(2,20) < 1$]. No validity effects were found for the jump cues at any SOA [$F(1,21) < 1$]. The jump cues did not produce horizontal shifts of attention.

Throw cues. A significant validity effect for throw cues was found overall [$F(1,21) = 8.84$, $p = .007$] and individually at 100-msec [$F(1,21) = 4.24$, $p = .05$] and 600-msec [$F(1,21) = 5.16$, $p = .03$] SOAs. An SOA effect indicated relatively longer RTs at the 100-msec SOA [$F(2,20) = 67.66$, $p < .0001$], but the validity × SOA interaction was not significant [$F(2,20) = 1.40$, $p = .27$].

Replicating Experiment 1, the throw (horizontal action) cue reliably produced lateral attention shifts consistent with the direction of the action. In contrast, the jump (vertical action) cues did not produce lateral attention shifts. Implied action cues appear to shift attention along a specific axis of motion, rather than toward the general side of space in which an active body faces.

EXPERIMENT 3

To support the action specificity of our results, block cues were created by placing blocks over the throw cues so that the two cue types were equated for major object angle, part relations, and distance to the target. To minimize any bias that the throw stimuli may have imposed on the participants' interpretations of the block figure, the block stimuli were always presented in the first block of trials. If simple perceptual cues account for the found validity effects, the block cues should be effective in producing validity effects similar to those in our implied action conditions. Alternatively, if the effect is specific to action, only the throw cues should produce validity effects.

Results

We conducted a repeated measures 2 (validity: valid, invalid) × 3 (SOA: 100, 300, 600 msec) × 2 (action: throw, block) ANOVA on RT data. Main effects of validity [$F(1,13) = 6.16$, $p = .027$], SOA [$F(2,12) = 27.06$, $p < .0001$], and action [$F(1,13) = 5.098$, $p = .042$] indicated longer RTs for the invalid cues, the shortest SOA, and block cues. Only the action × validity interaction approached significance [$F(1,13) = 2.11$, $p = .17$]. We had a priori predictions for each stimulus's interaction with validity. The throw stimulus produced a validity effect [$F(1,13) = 8.37$, $p = .01$] [$M_{\mathrm{RT}}(\text{invalid}) = 341.29$, $SE = 6.21$; $M_{\mathrm{RT}}(\text{valid}) = 332.87$, $SE = 6.43$], but the block stimulus did not [$F(1,13) = 2.02$, $p = .18$] [$M_{\mathrm{RT}}(\text{invalid}) = 351.13$, $SE = 6.69$; $M_{\mathrm{RT}}(\text{valid}) = 346.94$, $SE = 5.82$]. In contrast to the human action stimuli, the inanimate block cues that matched the action cues in low-level visual inputs did not significantly shift attention.

DISCUSSION

Human actions indicate important events to which others must respond. We investigated whether cues to impending directional body action shift spatial attention. If the perception of the human body involves predictive simulations that project forward to track unfolding body-motion events, it may also direct spatial attention. We used a centrally cued covert-orienting paradigm with nonpredictive cues. The validity effects indicate attention shifts. We compared two action cues (throw and run) with a nonaction cue (stand). Only the action cues produced validity effects, suggesting that implied action—not just trunk orientation—directed attention. Stand cues may not specify enough direction information to guide attention. The throw cues, which implied the fastest action, produced validity effects at both short (100-msec) and longer SOAs. They also produced the shortest overall RTs. However, it is possible that motor simulation of an action's speed, rather than the action's direction, shifted attention.

To demonstrate that the direction of the implied action was critical for attention shifts, we compared throw and jump actions that were equated as single events and for action speed but that differed in the implied axis of motion (horizontal and vertical, respectively). The overall RTs were comparable for the two cues, but only the throw cues produced horizontal validity effects. These results suggest that the perception of human action initiates a simulation process that shifts attention to regions of space consistent with the consequences of the action. A final experiment demonstrated that human action cues affect attention differently from inanimate cues, despite shared low-level visual features.

Together, these results are consistent with an attention system designed to produce adaptive and efficient reactions to a quickly changing environment (Kingstone et al., 2003; Wilson, 2002). Implied action can direct spatial attention, because it indicates spatial locations in which future activity is likely. The shifting of attention enables the anticipation of object motion and of where the consequences of action take place. Observers may be faster to respond to throw cues because of the action that the cues imply (an object in motion). Observing a throw may produce stronger attention shifts than observing a person running because one must move attention more quickly to track changes in space. Consistent with this notion, independent evidence indicates that anticipating the motion of a thrown object can lead participants to misperceive the very same trajectory even when the object is not, in fact, thrown (Kuhn & Land, 2006). Future studies can also examine attention differences between implied transitive (using objects) and intransitive actions. Observers may anticipate the consequences of thrown objects differently from those of body motion.

However, a pure functional attention explanation does not explain why the participants responded more quickly to *both* valid and invalid targets when the action cues implied more explosive action. Plausibly, action cues depicting fast, single-event action may influence the subsequent arousal of the observer. This heightened arousal leads to shorter RTs overall and may be a kind of motor priming (Wilson, 2006). Motor effort may prime spatial attention, and other factors could subsequently direct that attention. Thus, observing body actions may evoke both arousal and directional attention effects.

The motor simulation theory combines both functional attention and arousal components. When viewing another person performing an action, people engage in a motor simulation process to help them predict the outcome of that action (Knoblich & Flach, 2001). The neural bases of this process are increasingly well understood. The mirror system in the parietal and inferior frontal lobes is involved in both the perception and the production of action. The mirror system likely facilitates feedback from the perceptual activation of motor resources into perception, generating predictions of how the perceived event will unfold, thereby directing attention to that region of space (Shmuelof & Zohary, 2007). Similarly, in an fMRI study of viewing static action photographs, the activation in MT might be attributed to similar attention to action consequences (Kourtzi & Kanwisher, 2000). Support for mental simulation in the present study was found in the speeded overall responses to targets following cues implying faster movements. More importantly, responses were speeded to targets that appeared in spatial locations consistent with the directed outcome of the movement. The simulation process affects both perception and attention.

In conclusion, attention must be studied in terms of its real-world function. The actions of others direct attention because their consequences change the world. The finding that body actions shift attention highlights the importance of viewing attention as a functional system that is designed to do more than detect abstract targets. Researchers should consider the body and its capacity for action when attempting to understand the performance of attention in the everyday world.

AUTHOR NOTE

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