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Seeing and doing: Ability to act moderates orientation effects in object perception

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We investigated whether the impact of an object's orientation on a perceiver's actions (an orientation effect) is moderated by the perceiver's ability to act on the object in question. To do this, we manipulated the physical location of presented objects (Experiment 1) and the perceiver's action capacity (Experiment 2). Regardless of the physical distance of the object, manual responses were sensitive to the object's orientation (the orientation effect) when the object was within the participant's action range but not when the object was outside of the action range. These results support an embodied view of object perception and shed light on peripersonal space representation.

Keywords: Embodied cognition; Object perception; Peripersonal space; Action; Tool.

It has been proposed that perception is for action (Gibson, 1979; Goodale & Humphrey, 1998; Milner & Goodale, 1995; Proffitt, 2008). That is, perception of an object not only involves the encoding of an object's visual properties, but also activates motor plans based on the actions the object affords. For instance, when an individual perceives a graspable object (e.g., a tea cup), motor plans for grasping the object (e.g., the cup's handle) are thought to be automatically activated even if the perceiver has no intention to act. The *orientation effect*, in which manual responses are facilitated on the side congruent with the orientation of the presented object's handle, and the *size effect*, in which an object's size facilitates a congruent grasping response, support this idea (Fischer & Dahl, 2007; Phillips & Ward, 2002; Tucker & Ellis, 1998, 2001).

If this automatic motor activation serves to prepare an individual to act on a perceived object (Gibson, 1979; Milner & Goodale, 1995), then it follows that the degree of motor activation should vary according to the likelihood of acting on the object in question. For instance, if it is unlikely that an individual will act on an object because the object is beyond the individual's reach, the strength of motor activation elicited by the object should decrease.

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Existing data support the viewpoint that actability impacts the strength of motor processing. For instance, an individual's action related to an object is more likely to be primed by others' actions on this object when the object is within the individual's reach than when it is not, suggesting stronger motor simulation for observed actions on objects within reach. (Griffiths & Tipper, 2009). However, there is little evidence showing that objects within reach themselves elicit stronger motor processing than objects outside of reach. If anything, the data point in the opposite direction. For instance, Tucker and Ellis (2001) altered the physical distance between the object and the perceiver such that the object was either 15 cm or 200 cm away from the perceiver's hands. A size effect (in which an apple facilitated a power grip, and a grape facilitated a precision grip) occurred regardless of the objects' physical distance to the perceiver.

Yet, a closer examination of Tucker and Ellis (2001) reveals that the specific paradigm used may have masked the potential effects of the distance manipulation. Specifically, participants were instructed to indicate, by making a power or precision grip, whether the object presented was natural or artificial. Because participants had to process object kind information to perform the task, and each kind of object has a prototypical size, the grip type corresponding to the typical size could be activated merely because people have associations between objects and actions (Creem & Proffitt, 2001). Importantly, in a subsequent study, Tucker and Ellis (2004) found that lexicons referring to objects (e.g., the word "hammer") triggered a size effect statistically indistinguishable from those triggered by images of objects, suggesting that the size effect can be caused by semantic associations. In other words, although size effects can be produced by preparation to act, simple semantic associations can cause the same phenomena.

In the current study, we reexamined whether the extent to which object perception activates plans to act depends on the perceiver's ability to act on the object in question. We used the orientation effect (i.e., the phenomenon by which manual responses are facilitated on the side congruent with the position of the presented object's handle) to do this. Because orientation is not an inherent property of an object, unlike size, the orientation effect should not be produced by semantic association based on object kinds (Symes, Ellis, & Tucker, 2007). For instance, Derbyshire, Ellis, and Tucker (2006) showed that the orientation effect was not obtained when manual responses to an object were prompted after the removal of the object from view (whereas the size effect was obtained). Thus, the orientation effect seems better suited for testing whether actability moderates the impact of object perception on motor plan activation.

We manipulated the perceiver's ability to act on the object by manipulating (a) the spatial distance of the object from the perceiver, and (b) the perceiver's action capacity. In Experiment 1, we altered the physical distance between a presented object and the participant. The object was located either at a near location within the participant's reach (actable condition) or a far location outside of the participant's reach (unactable condition). We replicated the orientation effect found previously and showed that increasing physical distance reduced the orientation effect. In Experiment 2, we tested whether the orientation effect could be observed with a distant object when participants held long grasping tools that expanded their action capacity. We found the orientation effect when participants held long tools such that a distant object was within their action range (actable condition) but not short tools where the object remained outside of the perceiver's action range (unactable condition).

EXPERIMENT 1

Method

Participants

Twenty-two right-handed members of the University of Chicago community, aged 18–34 years, participated.

Stimuli

Stimuli consisted of 144 video clips (30 frames/s). Each clip consisted of a central fixation dot that would change its colour from grey to either red or green for 200 ms at various intervals after the onset of the trial. Participants were instructed to make speeded responses to indicate this change (see Procedure for details).

Behind the dot in each clip was a grey-scale 3D cup with a handle rotated in the background. The stimulus set-up was modelled after Fischer and Dahl (2007). To the participant, there appeared to be one single cup rotating continuously across trials. The left and right edges of the cup (including the handle) remained at about equal distance from the grey dot when the cup rotated to minimize shifts in visual attention. The cup rotated in either a clockwise or an anticlockwise direction at a speed of either 0.5 or 1 revolution/second across trials.

Across trials, the colour change occurred to prompt a response after the cup had completed 1–4 rotations (i.e., during the 2nd–5th rotation after the onset of each trial), so its timing varied. The key manipulation was that the dot changed its colour to prompt a response when the task-irrelevant cup was oriented toward the left half of the time and when the cup was oriented to the right half of the time (Figure 1). Thus, we had a 2 (response hand: left, right) × 2 (handle orientation: left, right) design for capturing the orientation effect.

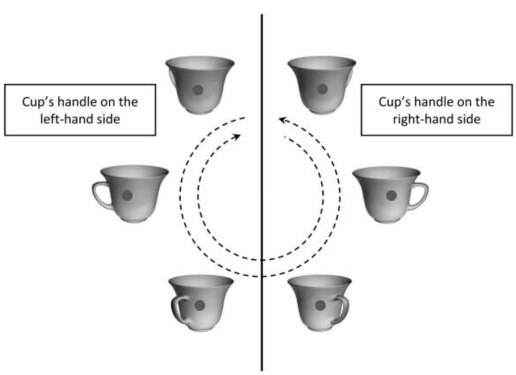

Figure 1. *Participants were prompted to make responses when the task-irrelevant cup was oriented toward the left half of the time and when the cup was oriented to the right half of the time.*

Apparatus and set-up

Stimuli were presented on a 15″ monitor (1,024 × 768 pixels; 60 Hz refresh rate) controlled by E-Prime 2.0.

Participants held a pair of 35-cm-long grasping tools (Figure 2) fixed on a platform throughout the study. When the participant performed a grasping action using the tool, the tool clicked a mouse located at its tip, and the computer recorded the participant's input. A cover was used to obstruct participants' hands from view (Figure 3).

In Experiment 1, the same 35-cm-long response apparatus was used in the actable and the unactable conditions (Figure 4). The two conditions differed only in the screen position: in the actable condition, the screen was positioned at 55 cm away (within reach), and in the unactable condition, it was 150 cm away (out of reach) from the participant. We were specifically interested in whether the strength of the orientation effect changed as a function of participants' ability to act on the cup.

Figure 2. *The grasping tool manufactured by ArcMate.com. (Note: The length of the tool in this picture does not reflect those custom-made for the current study.)*

Figure 3. *Photograph of the set-up. To view a colour version of this figure, please see the online issue of the Journal.*

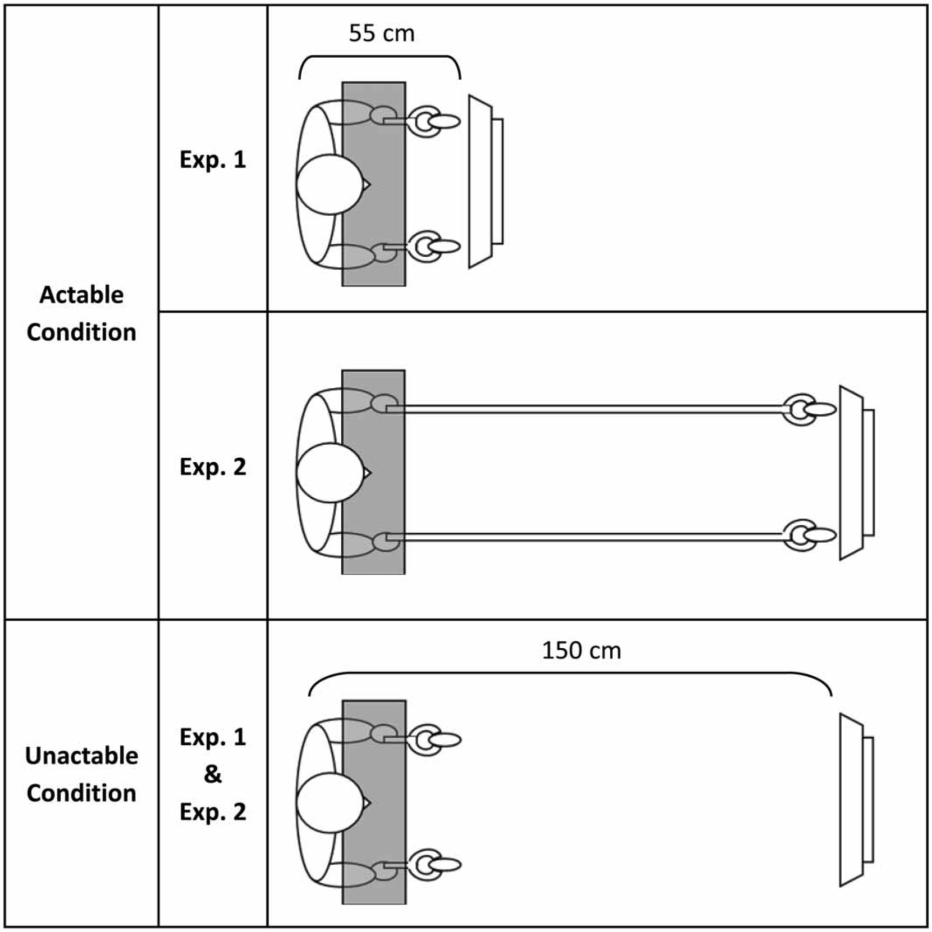

Figure 4. *Apparatus and set-up for the actable and unactable conditions in Experiment 1 and Experiment 2.*

Procedure

Participants' task was to report the fixation dot's change in colour by a manual grasping response as fast as possible, without regard to the cup. There were four 13-minute blocks (144 trials each) with breaks in between. Half of the blocks were in the actable condition. The other half were in the unactable condition. Block order was either "actable−unactable−actable−unactable" or reversed, counterbalanced across participants. Trial order within each block was randomized across participants.

For the first two blocks, participants responded with their right hand when the dot turned red and their left hand when the dot turned green. This mapping was reversed for the last two blocks. For each mapping, participants were required to achieve above 80% accuracy in practice trials where they responded to the changing target dot colour (without the rotating cup in the background) before the experimental trials began. After the experiment, participants were debriefed.

Results

Both reaction time (RT) and accuracy of the manual responses were recorded. Two participants were excluded from the analyses because they failed to achieve 80% accuracy across the four experimental blocks. Participants responded correctly to a majority of the trials (92.66%). For the remaining trials, participants made incorrect responses (3.22%), failed to make any responses (3.74%), or made responses before being prompted (0.37%).

Response time

RT analysis was based on accurate trials trimmed by two standard deviations around the mean of each subject in each condition (4.53% trials trimmed) after discarding trials below 200 ms and above 2,000 ms (0.19%). Thus, the following analyses are based on 95.28% of the correct responses.

We began by looking at RTs in the actable condition (object at near location) in which we expected to find an orientation effect (i.e., facilitated manual responses on the side congruent with the position of the presented object's handle). A 2 (response hand: left, right) × 2 (handle orientation: left, right) analysis of variance (ANOVA) revealed a significant Hand × Handle interaction,[1] $F(1, 19) = 13.52$, $MSE = 83.24$, $p = .002$. As seen in Figure 5, consistent with the orientation effect, right-hand responses were faster when the cup's handle was on the right-hand side ($M = 595.80$, $SE = 17.45$) than when it was on the left-hand side ($M = 602.70$, $SE = 17.77$), $t(19) = 2.56$, $p = .019$. Similarly, left-hand responses were faster when the cup's handle was toward the left-hand side ($M = 597.85$, $SE = 15.48$) than when it was toward the right-hand side ($M = 605.95$, $SE = 16.19$), $t(19) = 3.18$, $p = .005$. No main effects were significant (Fs < 1).[2]

In contrast, in the unactable condition (object at far location), the same 2 (response hand: left, right) × 2 (handle orientation: left, right) ANOVA revealed only a main effect of handle orientation, $F(1, 19) = 4.63$, $MSE = 219.10$, $p = .044$. Responses were faster when the handle was oriented to the left ($M = 613.50$, $SE = 17.29$) versus the right ($M = 620.55$, $SE = 17.87$; see "Combined Analysis" for discussion). Neither the main effect of response hand nor the critical Response Hand × Handle Orientation interaction was significant, Fs < 1.

Response error

Analysis of response errors did not alter our conclusions. In the actable condition, a 2 (hand: left, right) × 2 (handle: left, right) ANOVA revealed no main effect of response hand, $F(1, 19) = 2.73$, $MSE = 32.87$, $p = .115$, handle orientation, $F(1, 19) = 1.82$, $MSE = 8.27$, $p = .193$, or the interaction, $F < 1$. In the unactable condition, the same Hand × Handle ANOVA revealed a main effect of response hand, $F(1, 19) = 12.28$, $MSE = 8.63$, $p = .002$. Participants made more errors when they responded with their right ($M = 8.36\%$, $SE = 1.52\%$) than with their left hand ($M = 6.06\%$, $SE = 1.15\%$), although error rates were relatively low across both hands. There was no effect of the handle orientation or Response Hand × Handle Orientation interaction, Fs < 1.

Discussion

When an object is within participants' reach, manual responses are sensitive to the orientation of the object. Specifically, participants were faster to respond with their right hand when the handle of the task-irrelevant cup afforded right-hand grasping. Left-hand responses were faster when the cup's handle afforded a left-side grasp. This pattern of data (i.e., the orientation effect) was not seen when the object was outside of participants' reach.

The data from Experiment 1 suggest that perceivers' ability to act moderates the orientation effect. This action moderation runs contrary to

[1] The significant Hand × Handle interaction was not qualified by the timing of the prompt, cup rotation direction, or rotation speed in the current study. Thus, data across these factors were collapsed in subsequent analyses.

[2] Although significant, one might notice that our effects are somewhat small (i.e., actable condition: left hand, 8.1 ms; right hand, 6.9 ms; average, 7.5 ms). Nevertheless, the size of the orientation effect varies depending on experimental set-ups (Fischer & Dahl, 2007), and our effect size is common in the literature (around 5 ms, Experiment 1, Symes, Ellis, & Tucker, 2005; 6.5 ms, Experiment 2, Symes et al., 2007).

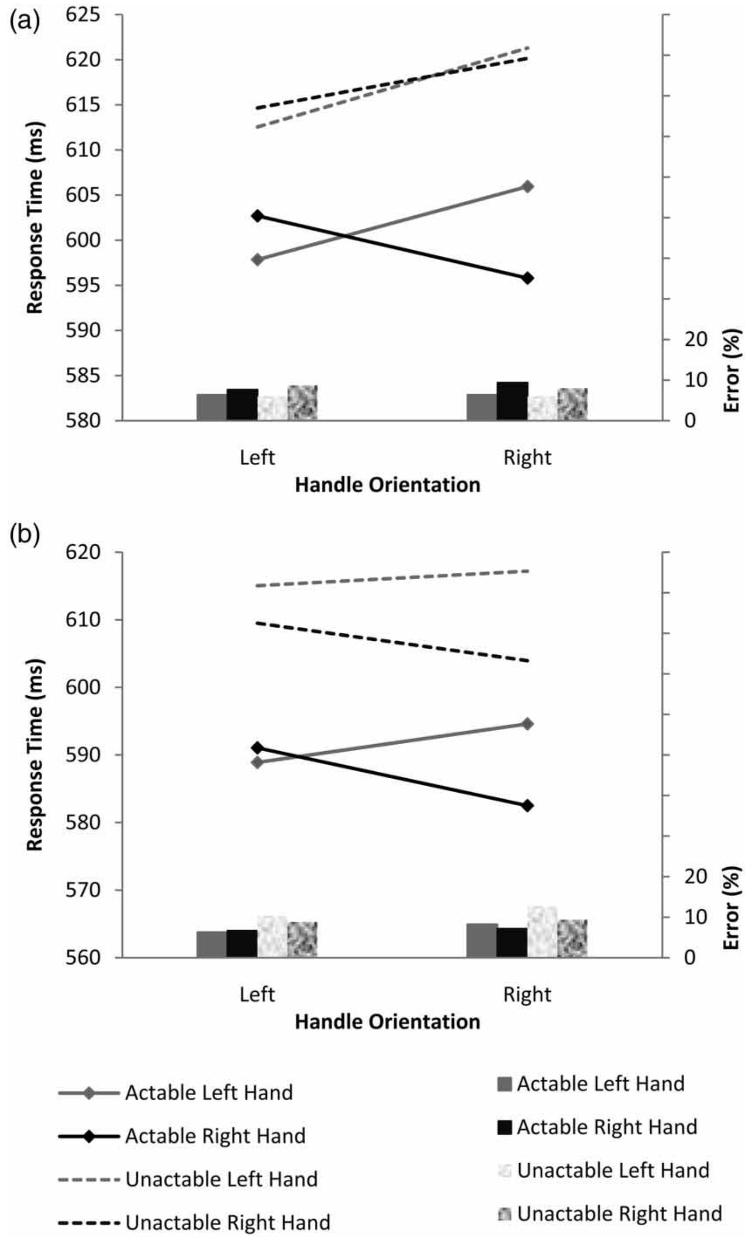

Figure 5. *Average response times and percentages of errors by conditions (actable vs. unactable) in Experiment 1 (a; upper panel) and Experiment 2 (b; lower panel).*

the size effect, probably because the size effect can be produced by semantic associations that do not depend on the distance between the object and the perceivers (Tucker & Ellis, 2001).

Although we speculate that changing physical distance affected the automatic activation of motor plans to act on the object in question, it is possible that changing physical distance affected factors irrelevant to affordance (e.g., changes in visual angles, reduced attention devoted to the task at hand). We address this issue in Experiment 2 by keeping object distance constant and instead manipulating participants' ability to act on the object by changing the length of the tools they held. If the orientation effect is observed with a distant object when the participants hold long tools (actable condition) but not short tools (unactable condition), this would suggest that it is the ability to act on the object that determines the strength of the orientation effect and not other action-irrelevant factors.

EXPERIMENT 2

Method

Twenty-one individuals, aged 18–25 years, with the same characteristics as those in Experiment 1, participated.

The stimuli, set-up, and procedure were the same as those in Experiment 1, with the following exception: The dot and the cup were always presented at a far location (150 cm away), and the actable and the unactable conditions were determined by the length of the tools used (Figure 4). Specifically, the tools were either 35 cm (short tools; as in Experiment 1) or 130 cm (long tools). The long tools expanded participants' action range to the distant object (actable condition) whereas the short tools did not (unactable condition).

Results

As in Experiment 1, 1 participant was excluded from the analyses because she failed to achieve 80% accuracy. Participants responded correctly to most of the trials (91.15%). For the remaining trials, participants made incorrect responses (2.73%), failed to make a response (5.76%), or made responses before being prompted (0.36%).

Response time

RT data were based on accurate trials trimmed using the same procedure as that in Experiment 1. The analyses below are based on 95.17% of the correct responses.

As in Experiment 1, we first looked at RTs in the actable condition (long tools). A 2 (response hand: left, right) × 2 (handle orientation: left, right) ANOVA revealed a significant Hand × Handle interaction, $F(1, 19) = 5.21$, $MSE = 194.73$, $p = .034$. Right-hand responses were significantly faster when the cup's handle was on the right-hand side ($M = 582.50$, $SE = 16.11$) than when it was on the left-hand side ($M = 591.05$, $SE = 18.04$), $t(19) = 2.17$, $p = .043$. Similarly, left-hand responses were somewhat faster when the cup's handle was on the left-hand side ($M = 588.90$, $SE = 17.39$) than when it was on the right-hand side ($M = 594.60$, $SE = 17.65$), $t(19) = 1.32$, $p = .210$. No main effects reached significance (Fs < 1). Thus, distant objects triggered the orientation effect when participants held long tools that increased their action range.

In the unactable condition (short tools), the same ANOVA revealed no significant Hand × Handle interaction, $F(1, 19) = 1.18$, $MSE = 252.27$, $p = .292$. There was no main effect of response hand, $F(1, 19) = 1.50$, $MSE = 1{,}181.17$, $p = .236$, or handle orientation ($F < 1$). As in Experiment 1, when objects were outside of participants' action range, the orientation effect was not observed.

Response error

In the actable condition, a 2 (response hand: left, right) × 2 (handle orientation: left, right) ANOVA showed a main effect of handle orientation, $F(1, 19) = 5.98$, $MSE = 4.91$, $p = .024$, such that participants made more errors when the handles were on the right-hand side ($M = 7.71\%$, $SE = 0.99\%$) than when they were on the left-hand side ($M = 6.49\%$, $SE = 0.99\%$; see "Combined Analysis" for discussion). There was no main effect of the response hand, $F < 1$, nor an interaction between the hand and handle, $F(1, 19) = 1.64$, $MSE = 6.40$, $p = .215$. In the unactable condition, the same ANOVA revealed no main effect of the response hand, $F < 1$, handle orientation, $F(1, 19) = 2.73$, $MSE =$

15.34, $p = .115$, or their interaction, $F(1, 19) = 1.73$, $MSE = 9.22$, $p = .205$.

Discussion

Similar to the first experiment, we found that object orientation affected manual responses when the object was presented within the participants' action range. Despite the distant location of the object, when long tools expanded participants' action range to the distant object (actable condition), participants' manual responses were sensitive to the object's orientation. In contrast, the same distant object did not show a significant orientation effect when participants held short tools such that the object remained out of participants' action range (unactable condition).

COMBINED ANALYSIS

If the orientation effect is indeed determined by whether the object falls within an individual's action range, then we should see the same pattern of results across the actable conditions of Experiments 1 and 2, despite the differences in object location (near vs. far) and tool length (short vs. long). Similarly, we should not find any orientation effect in the unactable conditions even if the data from the two experiments are combined.

A combined analysis demonstrated a similar orientation effect across the two different actable conditions in Experiment 1 and Experiment 2. That is, a 2 (experimental set-up: Experiment 1 short tool/near location, Experiment 2 long tool/far location) × 2 (response hand: left, right) × 2 (handle orientation: left, right) ANOVA on RTs showed only a significant Response Hand × Handle Orientation interaction, $F(1, 38) = 15.39$, $MSE = 138.99$, $p < .001$. For the right-hand responses, participants responded faster when the handle was on the right-hand side ($M = 589.15$, $SE = 11.77$) than when it was on the left-hand side ($M = 596.88$, $SE = 12.53$), $t(39) = 3.27$, $p = .002$. Similarly, for the left-hand responses, participants responded faster when the handle was on the left-hand side ($M = 593.38$, $SE = 11.51$) than when it was on the right-hand side ($M = 600.28$, $SE = 11.86$), $t(39) = 2.79$, $p = .008$.

For the unactable conditions, a similar three-way ANOVA revealed no significant main effects or interactions. Most importantly, there was neither an Experiment × Response Hand × Handle Orientation interaction, $F < 1$, nor a Response Hand × Handle Orientation interaction, $F(1, 38) = 1.01$, $MSE = 296.70$, $p = .321$. Even when the two experiments were combined, and there was potentially more power to find the orientation effect, the effect was not obtained when the perceived object was not within participants' reach.

Lastly, there was an unanticipated main effect of handle in the response time data in the unactable condition in Experiment 1 and in the error data in the actable condition in Experiment 2. This main effect did not emerge in any of the combined analysis, suggesting that the effect was aberrant.

GENERAL DISCUSSION

Together, Experiments 1 and 2 show that participants' ability to act on an object (determined by the object's physical location and the perceiver's action range) moderates the strength of the orientation effect. Regardless of the physical distance between the object and the perceiver, the orientation effect emerged when the object was within the perceiver's action range but not when the object was beyond the range.

We suggest that the semantic associations among object kinds, prototypical sizes, and corresponding actions cause the distance-independent size effect obtained by Tucker and Ellis (2001). These associations could have masked affordance processing during object perception so no relation was found between the strength of the size effect and participants' ability to act on the object.

In contrast, the orientation effect could not be masked by semantic associations because orientation is not inherent in object categories, and the strength of the orientation effect was found to be based on the perceiver's ability to act as demonstrated in the current study. Such a finding supports the idea that automatic motor activation during object perception prepares the perceiver for potential actions—an embodied view of object perception.

One might wonder whether the use of dynamic stimuli was critical for obtaining the moderation of the orientation effect by actability (i.e., manual movements facilitated by congruent object orientation, but *only when the object was within the participant's action range*). Though dynamic (more so than static) stimuli might trigger dorsal stream processing (Paradis et al., 2000), leading to enhanced bottom-up visuomotor transformation processes that could impact the orientation effect, we do not feel that these visuomotor transformation processes alone can explain all of our moderation effects. For instance, they cannot explain why changing the length of the tool used while maintaining the same dynamic visual stimuli in Experiment 2 would qualify the orientation effect. Thus, the dynamic property of the stimuli is probably not solely driving our effects.

There has been plenty of discussion regarding whether the orientation effect is triggered by spatial congruency (i.e., the overlapping of abstract spatial codes—Simon effect) between the stimulus and response (Riggio et al., 2008; Symes et al., 2005). The current study, by demonstrating how the likelihood to act moderates the orientation effect, suggests that a disembodied spatial congruency account cannot fully explain the orientation effect. An explanation that involves the body's ability to act is required.

Finally, our findings shed light on space representation. It has been suggested that the space closely around one's body is uniquely represented, and its range can be modulated by tools (Iriki, Tanaka, & Iwamura, 1996; Ladavas & Serino, 2008; Maravita, Spence, & Driver, 2003). The current study suggests that an objects' inclusion within one's action or peripersonal space is an important determinant of the extent to which motor plans to act on the object will be triggered.

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