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To point a finger: Attentional and motor consequences of observing pointing movements

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Abstract

Recent studies showed that action observation activates neural circuits used in performing the same action and facilitates execution of a similar motor program. This system for direct mapping of observed actions onto observer's own motor representation is considered critical for human imitation capabilities. The present study shows that observing a pointing action activates a representation of that action in anatomical space, irrespectively of whether the action is shown in allocentric or egocentric perspective. This finding is at odds with the studies on imitation which showed that humans tend to imitate in a spatially compatible (specular) way, as if looking in a mirror. Our results suggest that shared representations for actions are organized in the same spatial coordinates; however, a transformation of this representation might be required for imitation tasks in order to accommodate the goals of imitative action.

PsycINFO classification: 2323; 2330

Keywords: Anatomical action representation; Action understanding; Pointing and attention

1. Introduction

Understanding actions and intentions of other people is a crucial component of social interactions. Recent neuroimaging studies have demonstrated that simply observing an action performed by another person activates neural circuits used in performing the same action. According to the direct-matching hypothesis this 'mirror neuron system', which spans over inferior frontal and inferior parietal areas, forms a basis for action understanding (Iacoboni et al., 2005; Rizzolatti, Fogassi, & Gallese, 2001). Effects of action observation also extend to the observer's own actions. For example, observing an irrelevant finger movement facilitates the execution of a similar movement by the observer, due to the so-called ideomotor compatibility (Brass, Bekkering, & Prinz, 2001; Brass, Bekkering, Wohlschlager, & Prinz, 2000; Castiello, 2003). It has been proposed that imitative behavior in humans is based on the mirror neuron system (Iacoboni et al., 1999).

A question that emerges is whether a representation of an action performed by another individual is transformed when it is mapped to the body of the observer. If representation of the observed action is created through its direct-matching onto an internal motor representation of that action, then the anatomically congruent representation of the actor should be activated. Neuroimaging studies revealed that observing hand movements from the first person (egocentric) perspective indeed activates the respective contralateral motor areas and facilitates corticospinal activation induced through transcranial magnetic stimulation (TMS) (Aziz-Zadeh, Maeda, Zaidel, Mazziotta, & Iacoboni, 2002); but see Aziz-Zadeh, Koski, Zaidel, Mazziotta, and Iacoboni (2006).

However, it is not clear if such lateralization exists when people face each other, which is a more common situation for social interactions. However, it has been proposed that humans tend to imitate in a *specular* rather than in an

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anatomical fashion (Bekkering, Wohlschlager, & Gattis, 2000; Wohlschlager & Bekkering, 2002), meaning that it is more natural to imitate someone in a spatially compatible way, as if you are looking in a mirror, instead of performing a translation across the body's vertical midline. The only neuroimaging study that directly examined this question (Koski, Iacoboni, Dubeau, Woods, & Mazziotta, 2003) did not show any lateralized activation, but did show a greater bilateral activation of mirror neuron areas (particularly in inferior frontal and right parietal cortex) during specular than anatomical imitation. However, in the observation-only condition (Koski et al., 2003, Fig. 6) the reverse pattern of greater activity for observation of anatomical rather than specular actions was found in the supplementary motor area (SMA), posterior parietal and superior temporal sulcus (STS) areas. This discrepancy suggests that the matched representation possibly includes the perspective of the observed action, but this representation could be modified to accommodate imitation goals.

It has been argued that imitation tasks are based on hierarchical goal representation and not necessarily on the direct mapping of the observed action pattern. Since the main goal of imitative action is often an external object (the same object for the actor and imitator), the means of achieving the goal, i.e. the movement itself often constitutes a secondary goal (Bekkering et al., 2000; Wohlschlager & Bekkering, 2002). The imitative action tends to follow the primary goal and often uses the means that are most readily available, instead of copying the means used in the observed action. This could potentially explain the specular, rather than anatomical bias in the imitation tasks, in which the goal object activates the effectors on the same side of the body.

The first goal of the present study was to determine whether representation of actions performed by others is anatomically or specularly organized. Instead of an imitation task we used a variant of the classic Posner cueing paradigm (Posner, 1980), in which an actor pointed with his right or left hand to one of two lights on a desk. Participants were required to detect a particular color change that occurred in one of the lights following the action and to respond by pressing a key[1]. In one condition the observed action was shown in an allocentric perspective (actor faces the observer) and in another condition an egocentric perspective (looking over the actor's shoulder) was used[2]. It has been suggested that pointing gestures (Fischer & Szymkowiak, 2004; Langton & Bruce, 2000) trigger an attentional shift even when the cue does not possess any predictive value. Finding a cueing effect in our paradigm would serve as verification that the pointing movement had been attended to. The non-imitation nature of the task should preclude the specular bias and we therefore predicted that in both conditions observation of a pointing movement should activate the representation of anatomically congruent hand. The activation of anatomically congruent hand representation is likely to increase the readiness to respond by the congruent hand, which should be reflected in facilitation of response with that hand to the target, irrespectively of the perspective of the observed action.

The second goal of the present study was to determine whether the representation of the observed action is exclusively linked to the object of that action. Although attention is necessary for activation of action representation (Castiello, 2003), whether this representation persists even after attention is withdrawn is unknown. When the pointing gesture directs the observer to a wrong object (invalid cue) the activation of the hand representation can be discarded if it is linked exclusively to the object of action. In this case we would expect no effect of hand congruency. However, if action representation persists while attention is switched to the target location, the hand congruency effect should be present.

2. Method

2.1. Participants

Thirty-eight paid volunteers between 17 and 35 years of age (average age 21, 20 females) from Vrije Universiteit participated in the experiment. All participants were right-handed and reported normal color perception and normal or corrected to normal visual acuity. Nineteen were assigned to the allocentric perspective condition and another nineteen were assigned to the egocentric perspective condition[3].

2.2. Stimuli

In the *allocentric perspective* condition participants viewed movies of an actor sitting at a table and facing them. Both the torso and the arms of the actor were visible (Fig. 1, top). In *egocentric perspective* condition the camera was placed over the actor's shoulder, and therefore only the

[1] Since target positions were lateralized a choice response task would have resulted in a Simon effect (Simon & Small, 1969), with responses on the same side as the target initiated faster. This would have added another factor interacting with the factors of interest. Therefore, a Go/Nogo task that has been shown to minimize the Simon effect was chosen instead of a choice response task.

[2] The allocentric and egocentric views were chosen in such a way that they represented the most common situations encountered during social interactions, i.e. when looking at another person the arms and the torso are usually seen; for observation of own actions mainly the arms are seen (for the same logic, see Chan, Peelen, & Downing, 2004). This should maximize the congruency effects (whether anatomical or specular) for both allocentric and egocentric views.

[3] The main reason for not manipulating the perspective within-subjects was the possibility of observing order effects. Our suspicion was that even in a blocked design participants might be susceptible to changes in perspective even though perspective was irrelevant to the task. In addition, we were mainly interested in the direction of hand congruency effect in the allocentric perspective condition and the egocentric perspective condition served primarily as a control, since based on the previous studies we expected egocentric perspective to trigger anatomical congruency.

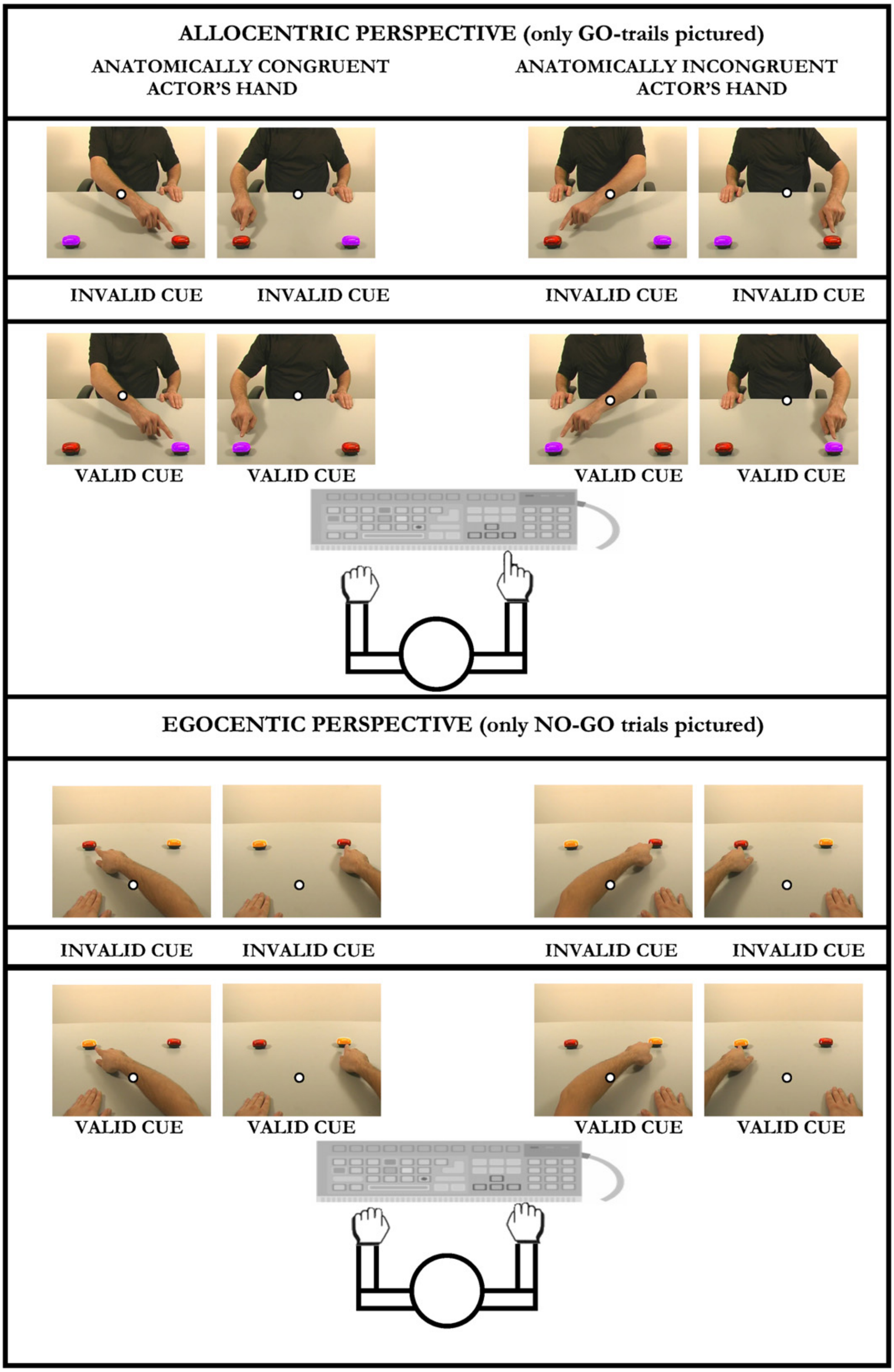

Fig. 1. Graphic illustration of different conditions in allocentric perspective (above) and egocentric perspective (below), only the last frame of the movie is shown. Participants had to press a key with a right index finger when the light turned from red to purple (above) and to withhold their response when the light turned from red to orange. The white circle depicts the location of the Go and No-Go targets, it was not present in the actual experiment. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

actor's arms were visible, as if they were the observer's own arms (Fig. 1, bottom). The actor was shown executing either straight or diagonal pointing movements towards one of the two red lights located on the left and right sides of the table, equidistantly from the actor and from the edges of the table.

Each hand movement consisted of 40 frames (690×569 pixels), presented at the rate of approximately 16.7 ms per frame. Therefore, the whole movement took approximately 668 ms. Hand positions and movement times were matched for both hands and for both diagonal and straight movements. Frames were presented and responses were collected using Eprime software. To control for possible subtle differences between the left and right sides of the actor's body during movement half of the stimuli were flipped across the vertical midline. The lights used in the experiment were red, and the color change from red to purple or from red to orange was created artificially by digital editing of the last frame of the movie.

2.3. Design and Procedure

Participants were seated 75 cm away from a computer screen. Each trial began with a 500 ms preview of the first frame of the movie showing an actor with his hands in the resting position and two red lights on the table. A white fixation dot was then superimposed on the center of the frame. Participants were instructed to maintain fixation on the dot throughout the trial. The movement of the actor started 500 ms after the presentation of the fixation dot. Immediately after the pointing movement was finished (the last frame of the movie) one of the lights on the table changed color from red to either orange or purple (Fig. 1). Participants were informed that the actor's pointing movements did not predict the location of the target, i.e. were directed to the target on 50% of the trials. Participants were instructed to respond (Go condition) by pressing a key ("/") on the keyboard with the right index finger when the light turned from red to purple and to withhold their response (No-Go condition) when the light turned from red to orange. Participants always responded with the right hand. Their response hand and the actor's hand were either anatomically congruent (i.e. participant used the right hand to respond and the actor used his right hand to point) or incongruent (i.e. participant used the right hand to respond and the actor used his left hand to point). The factors of actor's hand (left or right), target light (orange or purple), movement direction (straight or diagonal), cue validity (valid or invalid) and target side (left or right) were counterbalanced and mixed within a block of trials. Participants completed 18 experimental blocks of 32 trials each.

3. Results

Participants made very few errors (1%) by responding on No-Go trials. These responses were not analyzed. A mixed-effects ANOVA on correct mean reaction times with one between-subject factor (observed movement perspective) and three within-subjects factors (movement direction, anatomical congruency and cue validity) showed a main effect of anatomical congruency ($F(1,36) = 12.32$, $p < .005$) with participants responding faster when the cue and response hand were anatomically congruent than incongruent (Fig. 2). Hand pointing movement, although non-predictive, resulted in a cueing effect, with participants being faster when the hand correctly pointed to the target location ($F(1,36) = 55.12$, $p < .001$). The interaction between the anatomical congruency and pointing cue validity was not significant ($F(1,36) < 1$). It appears that participants were faster in responding on anatomically congruent trials irrespectively of whether the actor's hand correctly indicated the target location. When the actor pointed to a non-target location, the effect of anatomical congruency persisted, suggesting that action representation is not disrupted when spatial attention has to be shifted to the target location. Although the cueing effect appeared to be greater in the egocentric perspective condition, the interaction of perspective and cue validity was not significant ($F(1,36) = 2.33$, $p = .14$).

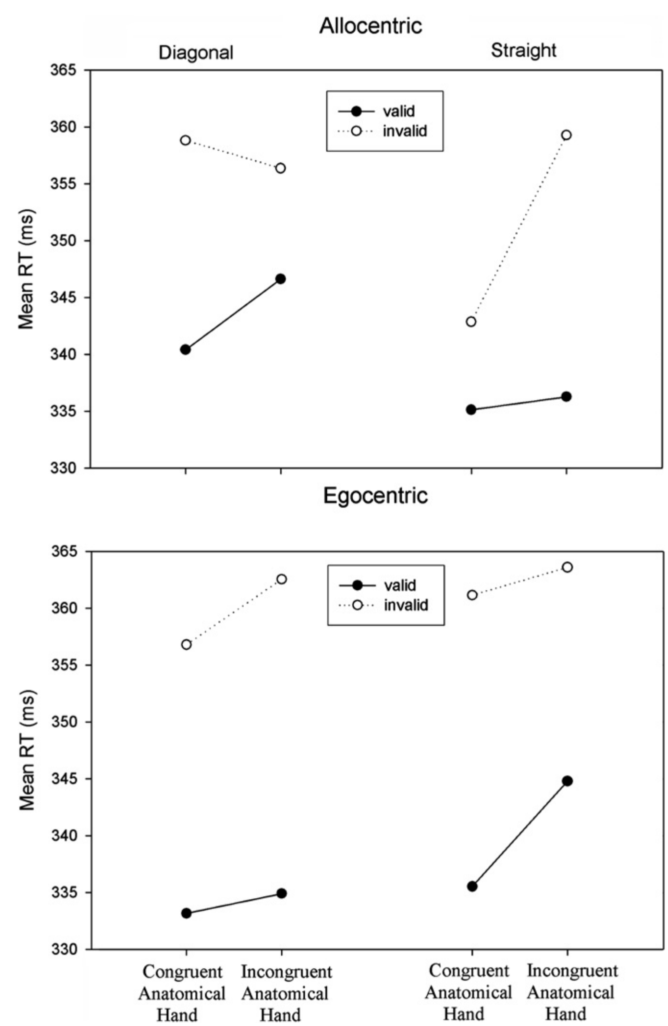

Fig. 2. Mean correct reaction time as a function of pointing direction, cue validity and anatomical congruency between the actors pointing hand and participant's response hand in allocentric and egocentric perspectives. The response hand and the pointing hand cue were congruent when the actor used the right hand to point and were incongruent when the actor used the left hand.

There was a significant interaction between the movement direction and the movement perspective ($F(1,35) = 10.01$, $p < .005$). It appeared that in the allocentric perspective condition responses following the straight movements were faster than responses following the diagonal movements. However, the effect was reversed in the egocentric perspective condition with diagonal movements followed by faster responses than the straight movements. Direction of a movement did not interact significantly with any other factors and no other factors or interactions were significant.

Planned comparisons within the allocentric and egocentric conditions confirmed a significant main effect of anatomical congruency in both conditions ($F(1,18) = 4.40$, $p < .05$ and $F(1,18) = 15.99$, $p < .005$, respectively) with participants responding faster when the cue and response hand were anatomically congruent than incongruent (Fig. 2).

4. Discussion

The goal of the present study was to examine the effects of observation of a hand pointing movement on attentional allocation and motor facilitation. This type of movement is considered a universal cross-cultural cue that evolved to direct attention of another person in social situations (Fischer & Szymkowiak, 2004; Langton & Bruce, 2000). Similar to previous results, we found that participants were faster and more accurate in responding to the target that was pointed to by the actor. Although the pointing movement was not predictive of the target location, it was attended and caused an attentional shift to the cued location.

Importantly, we also found that in both allocentric and egocentric perspective conditions participants were faster in responding to the target when the hand that the actor used to point was anatomically congruent to their response hand. This finding is consistent with the idea of ideomotor priming, showing that observing an action facilitates the execution of an action with an overlapping component; in our case such component was the anatomically congruent hand (Brass et al., 2000, 2001; Castiello, 2003). However, the existence of anatomical representation of action in allocentric perspective is at odds with the specular organization of action representation found in several previous studies using imitation tasks (Bekkering et al., 2000; Koski et al., 2003; Wohlschlager & Bekkering, 2002).

The special case of imitation comparing to mere observation of action has already been pointed out by researchers. Bekkering et al., 2000 suggested that the process of imitation is goal-directed and the significance of a goal in a particular task depends on its place in the goal hierarchy. Since the action by which the goal is achieved is often of secondary importance and the object of the action to be imitated constitutes the primary goal, there is a bias to imitate in a specular fashion. However, when the task is to observe a movement (as it is in the present study) anatomical and not secular representation of the observed action is revealed. In the imitation tasks in which the action is secondary this representation might need to be transformed to accommodate more important action goals.

A difference in cortical representation between imitation and observation conditions was also mentioned by Koski et al. (2003). Imitation of a specularly congruent hand action resulted in greater activation than imitation of anatomically congruent action in SMA, posterior parietal and STS areas. However, these areas responded more strongly to the anatomically congruent hand action in a control task, where participants had to merely observe the movement. It has been proposed that neurons in STS might play an important complementary role in action representation by providing a "pictorial" description of an action to the premotor mirror neuron areas (Gallese & Goldman, 1998; Koski et al., 2003), which in turn, translate it into a motor description necessary to reproduce the perceived action.

However, greater activation during specular than anatomical imitation reported by Koski et al., 2003 could also be in part due to spatial compatibility between the imitated and observed movements. In the specular imitation condition movements were always spatially compatible, while in the anatomical imitation condition they were always incompatible. This could also potentially explain why in some areas in the observation condition activation was greater for anatomically rather than specular congruent actions. As recently shown by Bertenthal, Longo, and Kosobud (2006) using similar stimuli, spatial compatibility has a substantial effect on reaction times. In fact, participants were a lot faster when they had to imitate spatially compatible finger movement than spatially incompatible finger movement. Importantly, when the task was to respond using a finger in the same spatial position, participants were also faster when the identical (middle or index) finger was used. However, the priming effect of spatial compatibility in the imitation task was substantially larger than the effect of finger compatibility in the spatial compatibility task.

Other recent evidence also suggests that representation of others could be encoded in anatomical coordinates. For example, Lozano, Hard, and Tversky (2007) demonstrated that the presence of action in a scene biases observers to describe the objects in the scene based on the actor's, but not their own egocentric spatial perspective. Anatomical congruency in shared representations was also recently shown in a sensory domain (Thomas, Press, & Haggard, 2006). The authors showed that observing irrelevant flashing cues on a model's body sped up the detection of tactile targets on the anatomically, but not specularly congruent body part. They proposed the existence of an 'interpersonal body representation' (IBR) that is shared between individuals and is anatomically organized.

Interestingly, one study showed a specular activation in the motor system when participants observed the actor performing an erroneous action, i.e. responding to the stimulus with the right hand when the left hand was designated as the correct response (van Schie, Mars, Coles, & Bekkering, 2004). It appears that participants were able to match the incorrect response of the observer by activating response on the same side of the body. It suggests that the mirror neuron system is rather flexible and can be modulated by the meaning of the observed response, instead of just being used for replication of its motor parameters.

Another interesting result from the present study was the absence of an interaction between the allocation of spatial attention and the strength of action representation. Attention is necessary for activation of action representation (Castiello, 2003); however, even when the actor's hand was pointing to the wrong location, the activation of action representation persisted while attention was shifted to the target location. We would like to point out that the target appeared immediately after the pointing movement was finished. Therefore, the representation of action once activated through attention to the observed action was not discarded soon after participants realized that their attention needed to be switched. This suggests that the action representation can be maintained even when attention is switched to a different object.

Similar pattern of results for actions in allocentric and egocentric perspectives suggests that such action representation is activated automatically, since any voluntary transformation needed to form an anatomical representation for allocentric perspective would be rather difficult, time consuming and more importantly, unnecessary. Such a direct mapping of other person's actions occurs as if the observer puts himself in the place of the actor and adopts his view of actions and objects (Lozano et al., 2007). A recent study showed that when participants were asked to intentionally perform such a mental rotation of perspective, their performance suffered dramatically (Franz, Ford, & Werner, 2007). Although we found no difference in the strength of action representation across perspectives, it is reasonable to assume that actions in egocentric perspective are generally less ambiguous and more familiar and should result in a stronger activation of motor system. Indeed, Maeda, Kleiner-Fisman, and Pascual-Leone (2002) using a more sensitive TMS method showed that observation of finger movements of a hand presented in allocentric perspective resulted in smaller motor activation than observation of a hand presented in egocentric perspective. Taken together, these findings extend the large body of research suggesting a common coding between perception and action (Prinz, 1997) to the extent that these representations can be shared between individuals (Brass et al., 2000, 2001; Castiello, 2003).

To summarize, we demonstrate that observation of a pointing action results in automatic attentional allocation to the pointed location and activation of an anatomical representation of that action. This representation is independent of whether the action is shown in allocentric or egocentric perspective and persists regardless of the validity of the pointing movement. We speculate that the observed anatomical representation is transformed into specular representation when the task becomes to imitate. Further research is needed to examine the influence of imitation tasks on action representation by directly comparing visuomotor priming tasks with imitation tasks.

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