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RESEARCH NOTE

Attention modulates the specificity of automatic imitation to human actors

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Abstract The perception of actions performed by others activates one's own motor system. Recent studies disagree as to whether this effect is specific to actions performed by other humans, an issue complicated by differences in perceptual salience between human and non-human stimuli. We addressed this issue by examining the automatic imitation of actions stimulated by viewing a virtual, computer-generated, hand. This stimulus was held constant across conditions, but participants' attention to the virtualness of the hand was manipulated by informing some participants during instructions that they would see a "computer-generated model of a hand," while making no mention of this to others. In spite of this attentional manipulation, participants in both conditions were generally aware of the virtualness of the hand. Nevertheless, automatic imitation of the virtual hand was significantly reduced—but not eliminated—when participants were told they would see a virtual hand. These results demonstrate that attention modulates the "human bias" of automatic imitation to non-human actors.

Keywords Automatic imitation · Mirroring · Virtual · Human bias

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Introduction

Perceiving others' actions activates one's own motor system (Rizzolatti and Craighero 2004). Behavioral (e.g., Kilner et al. 2003; Press et al. 2005; Tsai and Brass 2007) and neuroimaging (Perani et al. 2001; Tai et al. 2004) evidence suggests that such *mirroring* is stronger following perceived actions of humans than of non-human actors, the so-called "human bias" (Press et al. 2007). Recently, however, this proposal has been challenged, both on methodological (Jansson et al. 2007) and empirical (Gazzola et al. 2007; Oberman et al. 2007) grounds. It is thus unclear whether mirroring in humans is limited to the perception of human agents.

As a first step in answering this question, it is necessary to clarify that actions differ in terms of their movement kinematics as well as their surface form. Consider, for example, a grasp performed by a robotic arm. First, the movement kinematics will differ from natural grasp biomechanics; and second, the visual form of the robot will differ from that of a human hand. By contrast, an action performed by a human *moves* like a human, and it *looks* like a human. Either or both of these dimensions may influence the extent to which perceived actions will lead to mirroring. Studies have typically confounded these dimensions, comparing one condition in which natural looking human actions are performed in a biomechanically correct fashion with another condition in which non-human looking actions are performed in a biomechanically incorrect fashion (e.g., Kilner et al. 2003; Tai et al. 2004). Thus, it is not clear whether one or both dimensions is responsible for the observed differences.

Recently, we avoided this confound, investigating the sensitivity of automatic imitation to the biomechanics of perceived action, while holding the surface form of the agent constant (Longo et al. 2008). The stimulus was a computer-generated hand, with realistic and precisely manipulable bone and joint structure, allowing us to create biomechanically possible and impossible finger movements. Possible, but not impossible movements, elicited faster button responses to a compatible than an incompatible finger movement (indexing automatic imitation), if, and only if, the presence of both movement types had been explicitly mentioned to participants. This finding reveals that imitation is sensitive to the movement kinematics of observed actions, but only when observers are attentive to the movements as well as the goals of the action.

Is mirroring also sensitive to the human-like appearance of the actor? Press et al. (2005) investigated automatic imitation of human and robotic actions. Stimuli were still images of the final state of an action, such that they differed only in terms of their similarity to the human form, and not in terms of their movements. Automatic imitation was reduced—but not eliminated—by robotic stimuli, suggesting that surface form influences mirroring. Jansson et al. (2007), however, criticized this paradigm (among others) on methodological grounds, reporting data showing a comparable effect elicited by simple moving dots, suggesting that it is not specific to human stimuli. They suggested that apparent biological specificity may have resulted from differences in visual salience of human and robotic actions. This concern applies broadly, complicating interpretation of prior studies examining the biological specificity of mirroring.

Although this criticism is legitimate, it does not refute the possibility that the physical appearance of the actor will be relevant to the strength of the elicited imitation. In the current experiment, we avoided the previous stimulus confound by holding the stimulus constant, but modulating attention in a manner comparable to the way we tested the relevance of the veridicality of the movements for eliciting imitation (Longo et al. 2008). Participants were told either that they would see "a computer-generated virtual hand", or simply "a hand". Unlike previous research, this manipulation avoids low-level stimulus confounds, since stimuli are identical across conditions. If the human bias for mirroring extends to the surface appearance of an actor, automatic imitation of the virtual hand should be reduced or eliminated when attention is directed to its artificiality.

Methods

Participants

One-hundred and twenty healthy adults (73 female), between 18 and 38 participated. Sixteen additional participants were excluded because of error rates exceeding 10%.

Apparatus and materials

Stimuli were displayed on a 43.2 cm monitor, approximately 60 cm away. The virtual hand measured 13° of visual angle horizontally and 9° vertically, the video hand 15° by 8° (see Fig. 1). Finger movements displaced 1.9°

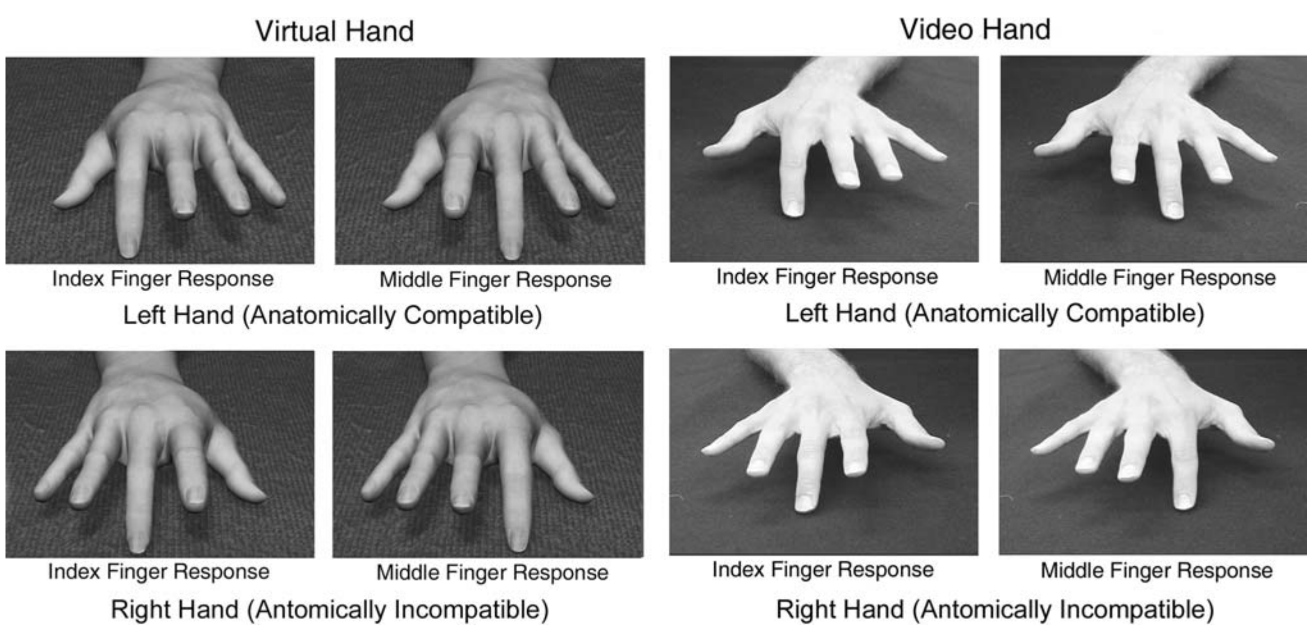

Fig. 1 Stimuli used in the experiment. *Left panel* virtual hand, *right panel* video hand. Movements of the index and middle fingers of the compatible (*left hand*) and incompatible (*right hand*) stimuli are shown. Note that these images are only the final frame of a five-frame movement sequence

for the virtual hand, 2.5° for the video hand. E-Prime (Psychology Software Tools, Pittsburgh, PA) was used for stimulus presentation and data collection. Details of the creation of the virtual hand are reported in Longo et al. (2008).

Design

Instructions were given verbally. Half of the participants were told that they would see short clips of a "computer-generated virtual hand", the others that they would see short clips of a hand, without mention of the virtualness of the hand. This statement was embedded within the overall instructions, and was not given any special emphasis. Within each group, half of the participants were shown the computer-generated hand and the video hand in alternating blocks, while the others only saw the virtual hand, to test whether the contrast between the video hand and the virtual hand would affect responses to the virtual hand or modulate the affect of instructions (cf. Ansorge and Wühr 2004).

We used the stimulus response compatibility paradigm of Bertenthal et al. (2006, Experiment 3b). Participants responded to the relative spatial position of the index and middle fingers of the stimulus, pressing a keyboard button with their right index finger if the stimulus finger farther to the left moved, and with their right middle finger if the finger farther to the right moved. Depending on whether a left or a right hand was displayed, the stimulus and response fingers were either anatomically compatible or incompatible. With a left stimulus hand, the stimulus and response finger were spatially and anatomically compatible (e.g., index finger response to index finger movement); in contrast, with a right stimulus hand, the stimulus and response fingers were spatially, but not anatomically compatible (e.g., index finger response to middle finger movement). Automatic imitation was computed as the reaction time advantage for compatible over incompatible stimuli (Bertenthal et al. 2006).

Procedure

There were 20 blocks of 20 trials, 10 trials each of index and middle finger movements, randomly intermixed. Blocks alternated between left and right hand stimuli. In conditions with both video and virtual hands, these stimuli alternated every second block. Order of initial blocks was counterbalanced. The experiment began with 16 unanalyzed practice trials.

Each trial lasted 3 s, beginning with the hand at rest for 533 ms. Three subsequent 38 ms frames presented the finger progressively moving down. A fifth frame (886 ms) showed the finger at rest on the surface. A final blue screen lasted 1,467 ms.

To determine awareness that the hand was virtual, participants were asked at debriefing to describe the hand stimuli they saw. All participants made clear that they had been aware that the stimulus was computer-generated.

Results

Trials where RT exceeded 800 ms and error trials were excluded from all analyses. A 2 × 2 × 2 factorial ANOVA was performed on automatic imitation of the *virtual hand* with compatibility (compatibile, incompatible) as a within-subjects factor, and two between-subjects factors: instructions (virtualness mentioned, or not) and contrast (only virtual hand presented, both virtual and video hands presented). Responses were faster to compatible (left-hand) stimuli (310 ms) than incompatible (right-hand) stimuli (318 ms), $F(1, 116) = 42.64$, $P < 0.0001$, replicating the effect we reported previously (Bertenthal et al. 2006; Longo et al. 2008). There was a significant interaction of compatibility and instructions, $F(1, 116) = 8.32$, $P < 0.005$ (see Fig. 2), with significantly less automatic imitation (measured as the difference between RT in the incompatible and compatible conditions) of the *virtual hand* when its artificiality had been mentioned (4 ms), than when it had not (11 ms). Significant automatic imitation, however, was observed in both conditions, $t(59) = 2.78$, $P < 0.01$, and $t(59) = 6.65$, $P < 0.0001$, respectively, demonstrating that drawing attention to the virtual hand reduced—but did not eliminate—automatic imitation. There were no other significant main

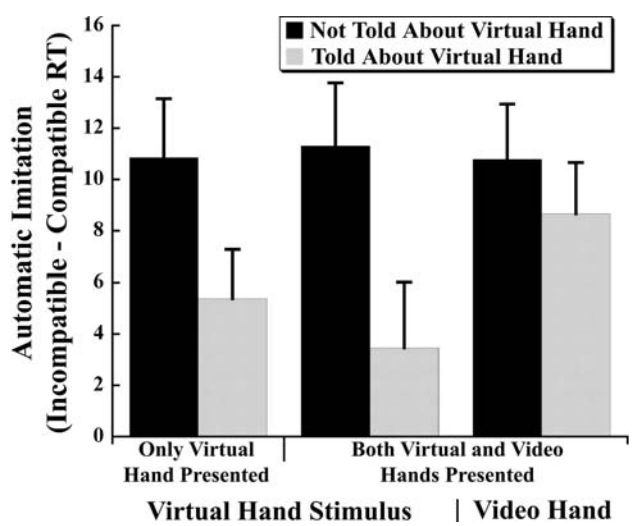

Fig. 2 Mean automatic imitation (incompatible RT–compatible RT) of the virtual and video hands as a function of instructions (reference to virtualness of hand or no such reference) and stimulus contrast (virtual and video hand or only virtual hand). *Error bars* are one standard error

effects or interactions (all P's > 0.20).[1] On debriefing, all participants indicated that they had noticed that the hand was computer-generated, suggesting that the effect of instructions influenced which aspects of the stimuli were attended, and not basic perception of the stimulus.

Significant automatic imitation of the *video hand* was observed both when attention had been drawn to the virtual hand (9 ms), $t(29) = 4.31$, $P < 0.001$, and when it had not (11 ms), $t(29) = 5.02$, $P < 0.0001$. There was no significant difference between these conditions, $t(58) = 0.72$. Thus, directing attention to the virtual stimuli selectively decreased the magnitude of automatic imitation elicited by the virtual hand but not the video hand, suggesting that instructions did not disrupt performance for non-specific reasons.

Non-parametric analyses revealed a similar pattern. Participants were more likely to show an overall compatibility effect (faster RT in compatible than incompatible trials) to the *virtual hand* when its artificiality was not mentioned (50 of 60, $P < 0.0001$, binomial test), than when it was (34 of 60, $P > 0.20$, binomial test), χ^2 $(1\ N = 120) = 10.16$, $P < 0.005$. This effect was observed both when the virtual hand was presented alone (26 of 30 vs. 19 of 30), χ^2 $(1\ N = 60) = 4.36$, $P < 0.05$, and when it was presented in alternation with the video hand (24 of 30 vs. 15 of 30), χ^2 $(1\ N = 60) = 5.93$, $P < 0.02$. In contrast, instructions did not significantly effect the likelihood of compatibility effects to the *video hand* (20 of 30 vs. 25 of 30), χ^2 $(1\ N = 60) = 2.22$, *n.s.*

Overall, errors were made on 2.63% of trials, and 0.69% of trials were excluded due to RTs exceeding 800 ms. The pattern of errors mirrored the RT data, suggesting that the RT effects are not the result of a speed-accuracy tradeoff.

Discussion

Drawing attention to the artificiality of a virtual hand reduces the amount of automatic imitation it elicits. Thus, an identical physical stimulus differentially elicits mirroring depending on whether participants are primed to interpret it as non-human. This result demonstrates the sensitivity of mirroring to the surface form of perceived actions, extending our previous findings showing such sensitivity to the manner in which actions are performed (Longo et al. 2008). Nevertheless, automatic imitation was observed across all conditions, suggesting that the amount of mirroring is reduced—but is not eliminated—for non-human actors, consistent with the findings of Press et al. (2005). It is noteworthy that this effect does not result from low-level perceptual differences between stimuli (cf. Jansson et al. 2007), because the stimulus presented across conditions was held constant.

Bailenson and Yee (2005) found similar reactions to being imitated by virtual characters as by real people. The present results complement those findings, showing the converse effect, that research participants imitate virtual actors similarly to real people. Furthermore, this effect is modulated by the direction of attention to the artificiality of the virtual actor.

This latter result converges with studies demonstrating top–down influences on mirroring (e.g., Bach et al. 2007; Grèzes et al. 1998; Kilner et al. 2006; Liepelt et al. 2008; Longo et al. 2008). Whereas Press et al. (2007) demonstrate bottom-up effects of associative learning modifying the human bias of automatic imitation; the present study shows that top–down effects of attention in the form of instructions can have similar effects. Such top–down influences provide a potential explanation for conflicting results in previous studies regarding the specificity of mirroring mechanisms to human actors (e.g., Gazzola et al. 2007 vs. Tai et al. 2004).

The issue of how virtual stimuli are treated by mirroring mechanisms is part of a larger debate regarding whether virtual stimuli are interpreted psychologically in the same way as real stimuli. Recently, two opposing views towards this question have emerged. On the one hand, some authors have suggested that qualitatively different neural mechanisms underlie perception of real and virtual stimuli (e.g., Han et al. 2005; Perani et al. 2001). In contrast, Reeves and Nass (1996) argue that virtual stimuli, and indeed all 'media', are treated as if they were real. Many recent studies have found that many social cognitive mechanisms seem to be applied regardless of the reality of the stimuli. For example, configural processing of faces and of bodies operates similarly for line drawings and photorealistic stimuli (Reed et al. 2003), while the same is true of brain areas such as the fusiform face area (Tong et al. 2000) and extrastriate body area (Downing et al. 2001). Similarly, moving geometric shapes can elicit robust perceptions of intentionality (Heider and Simmel 1944), and cartoons involving mental state reasoning are interpreted without difficulty, and activate similar brain areas as mental state reasoning about real people (Gallagher et al. 2000).

The present results help to reconcile these seemingly contradictory findings. Whether virtual stimuli are processed

[1] As participants in the virtual only condition received twice as many virtual hand trails as other participants, an additional analysis was conducted randomly selecting half the trials in each condition for those participants. Consistent with the above analysis, there was a significant main effect of compatibility, $F(1,116) = 33.34$, $p < 0.0001$, with faster RT in compatible (308 ms) than incompatible (316 ms) trials, and a significant interaction of compatibility and instructions, $F(1,116) = 9.92$, $p < 0.005$, with less automatic imitation when the artificiality of the hand had been mentioned (3 ms) than when it had not (11 ms).

in the same manner as real stimuli, at least in the case of mirroring, appears to depend on the direction of attention to different aspects of the stimulus. This is reminiscent of Polanyi's (1966) distinction between *focal* and *subsidiary awareness*. Subsidiary awareness (or tacit knowledge) refers to situations in which we are tacitly, or implicitly, aware of aspects of stimuli that are functionally suppressed. We generally perceive effortlessly the people or scenes depicted in painting, *as if* they were real, even as we know full well (if tacitly) that we are looking at splotches of paint on canvas. In contrast, attending focally to the manner of painting creates a very different percept: we see a canvas and blobs of paint, rather than the scene depicted (Gombrich 1960). Thus, we perceive paintings as if they were real only when knowledge of their artificiality remains tacit, in subsidiary awareness; when this knowledge is raised into focal awareness, we cease to perceive painting as if they were real (Polanyi 1970).

We suggest that virtual stimuli are perceived in the same way. By default, the knowledge of the artificiality of virtual stimuli remains in subsidiary awareness, so that virtual stimuli are processed as if they were real (cf. Reeves and Nass 1996). In contrast, when attention is drawn to this information, it is raised to focal awareness, such that we cease to perceive virtual stimuli as real (cf. Han et al. 2005). The reduced automatic imitation we observed when attention was drawn to the artificiality of the hand would, thus, result from the raising of this knowledge from subsidiary into focal awareness. Schilbach et al. (2006) suggest that the crucial factor determining the extent to which social cognition is applied to virtual stimuli is the sense of 'social presence' evoked by the stimulus. We suggest that social presence specifically, as well as the feeling of presence in virtual environments more generally, may arise just when the artificiality of the virtual stimuli remain in subsidiary, rather than focal, awareness.

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