Something in the way she moves me: morphology and motion of observed goal-directed and pantomimed actions

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Observing other actors excites our own motor system (Fadiga, Fogassi, Pavesi, & Rizzolatti, 1995) and alters behavioural output (Kilner, Paulignan, & Blakemore, 2003; Ocampo & Kritikos, 2010). The features of the actor that drive these alterations, however, are unclear. In the present study, we focused on the appearance of the actor versus the intrinsic biological motion (BM) of her action, and the category of action—goal directed as compared with action—nongoal directed (pantomimed).

In ideomotor priming paradigms, observed actions trigger corresponding actions in the observer. Participants typically view videos of a hand lifting the middle or index finger, and respond by making the same (congruent) or opposite (incongruent) lift. In the crucial comparison, symbols (shapes or numbers) determine responses. Response times (RTs) are faster to fingers than to symbols (Brass, Bekkering, Wohlschläger, & Prinz, 2000; Jonas et al., 2007). Moreover, watching humans alters the spatial components of observers' actions. Kilner et al. (2003) had participants make horizontal or vertical movements with their arms while watching either a human or a robot make congruent or incongruent actions. Participants' trajectories were more variable during incongruent than congruent actions, but only when watching the human actor. Kilner et al. argued that this “motor contagion” is specific to watching another human, and that the human visuomotor system processes human and robot actions differently.

The main impetus for the present study was that appearance is conflated with BM: We attempt to disambiguate the two.

BM is the movement pattern of animate beings from degraded signals, typically point lights placed at joints (Blake & Shiffrar, 2007; Johansson, 1973). Observers can distinguish BM from arbitrary but coherent motion (Hiris, Krebeck, Edmonds, & Stout, 2005) and can extract identity, gender and affect (Pollick, Fidopiastis, & Braden, 2001; Pollick, Paterson, Bruderlin, & Sanford, 2001). Observers recognize their own motion most accurately, then that of their friends, whereas “stranger” recognition is at chance (Loula, Prasad, Harber, & Shiffrar, 2005). When displays are inverted, self- as well as other recognition is at chance. Thus, motor and visual experience of the actor are required for recognition, but not low-level information about form and motion (Loula et al., 2005). We cannot assume the same influence on the motor output of the observer, however.

Most studies showing an advantage in action execution when watching human actors have used nongoal-directed actions (e.g., Brass et al., 2000; Kilner et al., 2003). Importantly, pantomimes have longer movement duration and smaller maximum grasp than do goal-directed actions (Goodale, Jakobson, & Keilor, 1994). Goodale et al. (1994) postulated that goal-directed movements are computed online, whereas pantomimes are based on stored representations of objects. Thus, ideomotor apraxics have difficulty pantomiming meaningful actions, which is ameliorated when they are able to use the object (Buxbaum, Sirigu, Schwartz, & Klatzky, 2003). Conversely, the pantomimed reaches of the visual agnostic patient DF to familiar objects were intact because she had a premorbid stored representation of these. She could not pantomime to novel objects, however, because she did not have stored representations and could not construct a visual one (Goodale et al., 1994). Thus, when asking whether motion or appearance of the actor has an impact on the actions of observers, we also need to specify whether they are goal directed or pantomimed.

Using motion capture software, we recorded human pantomimed or goal-directed actions, also exporting them

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as a point displays (PD) of identical BM parameters. Participants made congruent and incongruent responses to the real or the PD stimuli. Observing the real actor should benefit performance if the visuomotor system processes human appearance preferentially, with faster responses and changes in the grasp aperture than in the PD or no-actor baseline. Because real and PD displays contained the same BM, if BM is crucial, then both the human and PD displays will speed up responses and change grasp width relative to baseline (no-actor) conditions. These effects should be evident when observers execute pantomimed actions rather than goal-directed ones, consistent with previous paradigms implementing nongoal-directed actions (Brass et al., 2000; Jonas et al., 2007; Kilner et al. 2003).

Method

Participants

Thirty volunteers from the School of Psychology (University of Queensland; 12 females; age range from 18 to 34 years, $M = 25.05$, $SD = 6.20$) provided informed verbal consent. All were right-handed with normal or corrected-to-normal vision.

Fig. 1 Depiction of the experimental workspace, monitor, and motion capture cameras

Apparatus and stimuli

We recorded the actor simultaneously with a digital camcorder and three Qualisys ProReflex infrared motion capture cameras. Only the actor's torso and right hand and arm were visible against a black background. We placed 12 reflective markers—one on each fingernail, two on the wrist—on the styloid process of the radius, head of the ulna, ulna and radius proximal to the elbow, and bicep. We exported motion capture recordings of these markers to video to construct the PD display of the same action (and see Campanella, Sandini, & Morrone, *in press*).

The actor practiced the actions with a metronome to promote equivalence of duration. For goal-directed actions, the actor's movement duration was 625 ms, peak grasp was 99 mm, and maximum deviation of trajectory from a hypothetical straight line in the X plane was 24 mm. For pantomimes, movement duration was 660 msec, peak grasp was 99 mm, and maximum X plane deviation was 29 mm. We removed frames at the

Fig. 2 Trial sequence for baseline condition (panel a, go trials; panel b, no-go trials), and for experimental trials (panel c, watching real hand condition; panel d, watching PD hand condition). The tone to trigger observers' movement was administered 400 ms after the onset of the gray square (baseline trials) and 400 ms after the onset of the video (experimental trials)

Fig. 2 (continued)

very start of the movement (where hand displacement is minimal and does not affect peak velocity and acceleration) to normalize movement duration at 600 ms for the final displays, ensuring equivalence of duration and peak grasp timing.

The actor's hand rested on the table, with thumb and index finger in gentle opposition. For goal-directed actions, the actor reached for and grasped the rim of a plastic yellow drinking flute, positioned 35 cm from the starting position of the hand and 15 cm to the left of the midline. For pantomimes, the actor mimed reaching for and grasping an imaginary drinking flute positioned in the same location. For PD goal-directed actions, we inserted the image of the drinking flute into the video at the corresponding location.

We presented displays (15 cm × 23 cm) on the monitor and triggered motion-capture cameras using Presentation (Neurobehavioral Systems). We calibrated cameras to <0.3 mm accuracy, recorded at 100 Hz and exported to MATLAB to calculate initiation time and peak Grasp.

Participants sat at a table (73 cm × 160 cm × 80 cm) with a monitor aligned to their midline and that was 70 cm from the eyes. They wore passive reflective markers (12-mm diameter) on the distal process of the ulna and radius, index fingernail and thumbnail of the right hand. Their right hand was pronated on the tabletop, with the index and thumb in light contact (see Fig. 1 for a representation of the set-up) and returned to this position at the end of each trial. We instructed participants to grasp the rim of the flute, ensuring consistency

between participants and minimizing the possibility that markers were obscured by the sides of the flute.

Participants fixed their gaze on a cross (5 cm², 500-ms duration). This was followed by a gray square (2 cm²) for the baseline condition (see Fig. 2a and b) and videos in the experimental trials (600-ms duration) of either the actor's real or PD hand reaching to grasp (see Fig. 2c and d for a depiction of the real and PD trial sequences, respectively). On all trials, a high (5 kHz) or low (2 kHz) tone that occurred 400 ms after onset was the signal to initiate the goal-directed or pantomimed action. The tone coincided with the timing of the actor's peak grasp, ensuring that the actor's kinematics were unfolding during the participants' reach, rather than an internal representation (Kilner et al., 2003). Participants reached for a plastic yellow champagne flute (height 13 cm; width 5.5 cm at the rim), positioned 35 cm from the starting position of the hand and 15 cm either to the left or right of the midline. In goal-directed actions, participants reached to the flute. In pantomimed actions, they enacted a "pretend" reach to an imaginary flute at the corresponding location in the opposite space. Flute location was counterbalanced across blocks.

Procedure

Participants were assigned to "watching real hand" or "watching PD hand" groups, in counterbalanced order, to avoid activating real hand internal representation on PD trials. They gave informed consent and received instructions on the monitor as well as verbally. All participants reached with the right hand.

Initially, in the baseline blocks of trials, they reached to either a real flute (goal-directed baseline) or an imaginary one (pantomime baseline) in response to a gray square appearing on the screen. At the start of baseline trials, participants fixated on the central fixation cross for 500 ms; the gray square then appeared for 600 ms. A tone sounded 400 ms after the gray square onset. On hearing a high tone, they reached for and picked up the flute (goal directed; 10 trials); at the low tone, they “pretended” to reach to an imaginary flute (pantomime; 10 trials). Low- and high-tone assignment was counterbalanced between participants. There were 24 trials in the baseline condition, including four no-go trials (the gray square turning green for 100 ms, 500 ms after it was presented) in which they withheld their response.

Subsequently, the experimental trials were administered in four identical blocks with a 3-min break between each block. Participants watched a video of a real or PD actor making a reaching action. In the goal-directed trials,

participants reached for and grasped the drinking flute. In the pantomime conditions, they pantomimed reaching to and grasping an imaginary flute. In the congruent conditions, participants made the same action as the actor at the tone (e.g., goal directed to goal directed). In the incongruent condition, they made the opposite action to the actor at the tone (e.g., goal-directed to pantomime).

In experimental trials, participants fixated on the central fixation cross for 500 ms. This was followed by the stimulus (real or PD; goal directed or pantomime; duration 600 ms). On all trials, the tone sounded 400 ms after stimulus presentation. In total, across the four blocks there were 280 experimental trials: 60 trials for each goal directed and pantomimed action for each of the congruent and incongruent conditions. There were also 40 no-go trials, in which display (real hand or PD) duration was 500 ms, and then turned green for 100 ms. The position of the real flute (left or right) was counterbalanced between blocks.

Fig. 3 Initiation time (with standard error bars) for responses to baseline trials, watching real hand and watching PD hand (panel a), and for executed goal-directed and pantomimed actions while watching goal-directed and pantomimed actions for the real and PD hands groups (panel b)

Table 1 Post-hoc comparisons averaged across groups for peak grasp between baseline and experimental conditions (top panel) and for actions congruent and incongruent to the model (bottom panel)

Comparison	<i>t</i> (28)	<i>p</i>
Baseline Making goal directed vs. watching and making goal directed	0.323	.749
Baseline making goal directed vs. watching goal directed but making pantomimed	1.085	.723
Baseline pantomimed vs. watching and making pantomimed	1.085	.287
Baseline pantomimed vs. watching pantomimed but making goal directed	.834	.412
Watching and making goal-directed vs. watching goal directed but making pantomimed	5.907	.0001
Watching and making goal-directed vs. watching and making pantomimed	0.040	.969 <i>ns</i>
Watching and making pantomimed vs. watching pantomimed but making goal directed	8.149	.0001
Watching goal directed but making pantomimed vs. watching pantomimed but making goal directed	3.683	.001

Design

We conducted a $2 \times 2 \times 2$ mixed factors ANOVA, with hand (real, PD) as the between-groups factor, and with observed action (goal directed, pantomimed) and executed action congruence (goal congruent, incongruent) as the within-subjects factors.

We analyzed IT (the time between the tone signaling the start of the movement and the displacement of the radius marker by 1 mm) and peak grasp (PG; the maximum distance, in millimeters, between the thumb and index markers attained during the movement). Because of technical difficulties (markers out of range of the cameras), kinematic data were unavailable for approximately 2% of trials for each participant.

Results

Initiation time

Comparisons with baseline trials There was no significant difference between baseline (no actor) goal-directed and pantomimed trials for IT (790 ms, $SD = 205$; and 813 ms, $SD = 173$, respectively, $t(19) = 0.750$ $p = .459$); thus, these two were collapsed for further comparisons. IT was faster when watching the real hand as compared with the baseline condition (686 ms, $SD = 113$; and 811 ms, $SD = 128$, respectively; $t(14) = 3.710$ $p < .01$, see Fig. 3a). Conversely, baseline IT (watching the square) was not different from watching the PD (741 ms, $SD = 179$; $t(14) = 1.804$ $p = .093$).

In other words, there is a benefit in performance when watching a real hand performing an action, as compared with watching a symbolic stimulus.

Comparisons for the experimental conditions In contrast with comparisons against the baseline condition, the group (hand) main effect was not significant, $F(1, 27) = 1.149$, $p > .05$, $\eta_p^2 = .041$.

The main effect of observed action was significant: IT to goal-directed actions was faster than to pantomimed actions (687 ms, $SD = 140$; and 741 ms, $SD = 156$, respectively; $F(1, 29) = 55.778$, $p < .0001$, $\eta_p^2 = .674$). Executed action congruence was also significant: IT was faster when participants made the same rather than the opposite action as the actor (704 ms, $SD = 145$; and 724 ms, $SD = 151$, respectively; $F(1, 27) = 24.960$, $p < .0001$, $\eta_p^2 = .480$).

Finally, there was a significant Observed Action X Executed Action Congruence interaction, $F(1, 27) = 11.250$, $p < .01$, $\eta_p^2 = .294$ (see Fig. 3b and Table 1 for the individual comparisons). Post-hoc comparisons showed that IT was faster when performing and watching a goal-

Fig. 4 Peak grasp (with standard error bars) for responses to baseline trials and for executed goal-directed and pantomimed actions while watching goal-directed and pantomimed actions for the real and PD hands groups

Table 2 Post-hoc comparisons for peak grasp for the “watching real hand” (top panel) and “watching PD hand” (bottom panel) groups, for congruent and incongruent actions to the model

Comparison		<i>p</i>
Real hand group	Watching and making goal directed vs. watching goal directed while making pantomimed	<i>t</i> (14) 2.646 .019
	Watching and making goal directed vs. watching and making pantomime	<i>t</i> (14) 6.390 .0001
	Watching and making pantomimed vs. watching pantomimed while making goal directed	<i>t</i> (14) 2.285 .038
	Watching goal directed while making pantomimed vs. watching pantomimed while making goal-directed	<i>t</i> (14) 7.729 .0001
PD hand group	Watching and making goal directed vs. watching goal directed while making pantomimed	<i>t</i> (12) 1.149 .273 <i>ns</i>
	Watching and making goal directed vs. watching and making pantomimed	<i>t</i> (12) 2.293 .041
	Watching and making pantomimed vs. watching pantomimed while making goal directed	<i>t</i> (12) .137 .893 <i>ns</i>
	Watching goal directed while making pantomimed vs. watching pantomimed while making goal directed	<i>t</i> (12) 2.488 .029

directed action (congruent) than when watching a goal-directed one but performing a (incongruent) pantomimed one. However, executing a goal-directed action was no quicker than a pantomime action when participants were watching a pantomime action. Conversely, watching goal directed actions was associated with faster IT than watching pantomimed ones, both when making in response goal-directed ones or pantomimed ones.

Peak grasp

Comparisons with baseline trials In contrast with IT, there was a significant difference between baseline goal-directed and pantomimed trials for PG, so that grasps to the flute (i.e., goal-directed actions) were larger than pantomimed grasps (105.00 mm, *SD* = 16.97; and 91.99 mm, *SD* = 14.20, respectively, *t*(27) = 5.6594; *p* < .0001, and see Fig. 4). Comparisons between baseline and experimental trials were nonsignificant (see Table 1).

Comparisons for the experimental conditions The observed action main effect was significant: Participants had larger grasps when watching goal-directed rather than pantomimed actions, *F*(1, 27) = 32.416, *p* < .001, η_p^2 = .555. The Observed Action X Executed Action Congruence interaction was significant, *F*(1, 27) = 8.452, *p* < .01, η_p^2 = .245. This was due to a stronger effect of “observed action” type on PG when participants executed a congruent action than when the executed action was incongruent with the observed action.

However, a significant three-way interaction involving Hand X Observed Action X Executed Action Congruence moderated this interaction, *F*(1, 27) = 4.472, *p* < .05, η_p^2 = .147; see Fig. 4). Post-hoc comparisons for each group (real, PD; see Table 2) showed that for participants watching the real hand making goal-directed actions, PG was wider when they responded with pantomimed rather

than with goal-directed actions. Conversely, when they were watching the real hand make pantomimed actions, PG was wider when participants responded with goal-directed, compared pantomimed with actions. Concerning action congruence, seeing and making goal-directed actions caused wider PG than seeing and making pantomimes. Watching goal-directed actions while making pantomimes caused wider PG than watching pantomimes while making goal-directed actions. For the PD group, each of these comparisons was nonsignificant (see Table 2). The differences between groups for each of the conditions were also nonsignificant (see Table 3).

Discussion

We asked whether observers process human appearance of actors preferentially to BM, and whether the effects are more prevalent for observed and executed pantomimed rather than goal-directed actions. Watching either a real or the PD hand facilitated IT comparably. Beyond this fundamental effect, watching goal-directed actions facilitat-

Table 3 Post-hoc comparisons for Peak Grasp between the ‘watching Real hand’ and ‘watching PD hand’ groups, for congruent and incongruent actions to the model

Comparison	<i>t</i> (12)	<i>p</i>
Real hand watching and making goal directed vs. PD hand watching goal directed and making goal directed	.306	.765
Real hand watching goal directed while making pantomimed vs. PD hand watching goal directed while making pantomimed	.480	.640
Real hand watching and making pantomimed vs. PD hand watching and making pantomimed	.486	.636
Real hand watching pantomimed while making goal directed vs. PD hand watching pantomimed while making goal-directed	.685	.506

ed IT regardless of the executed action. Similarly, Liepelt, Prinz, and Brass (2010) showed that human- and wooden-hand postures prime RTs equally for transitive (goal-directed) and intransitive (nongoal-directed) actions. We also analyzed PG, a spatial behavioral measure. When observers watched the real hand making goal-directed actions, their PG for executed pantomimed actions was wider than their PG for goal-directed actions. The effect was exaggerated when there was a goal present in the observed action but the executed action was pantomimed. We found no such pattern of influence for the PD hand. This suggests that the Real hand contains information that modulates motor behavior of the observer.

The fact that the actor's goal alters the observer's action suggests that observers process and integrate into their executed action the physical properties of a goal that is not their own. Thus, any "motor contagion" in the present paradigm is attributable in part to goal presence, as well as to the appearance of the actor. We postulate that pantomimed actions are more vulnerable than goal-directed ones to the goal. This could be because the internal representation of the observer's goal is replaced by the actual presence of the actor's goal.

We speculate that responding to human actors engages more than one visuomotor mechanism and may manifest differently in various behavioral measures (in this case, IT vs. PG). Thus, although appearance of the actor influences speed of responses, observed and executed action type (goal directed vs. pantomimed) alters grasp size, a spatial response. The advantage of our paradigm is that we can detect the influence of the actor as the observer's action unfolds—that is, whether we integrate information from the actor into our own action. Here, we have been able to compare behavioral responses to two actor displays with a common feature, BM, against baseline conditions (responding to a square). We point out, however, that the exact nature of the information is still unclear and requires presentation of human actors with nonbiological motion, and vice versa. For example, it is possible that the "human" video provides a greater aggregate of information than the black and white dots of the PD display. After all, participants can recognize their friends from PLDs, but not better than they can from actual videos. The effect cannot be attributed to the presence of the flute in the PD goal-directed videos: The human but not the PD goal-directed actions modulated PG. It may be that other features of the actor also

influence action execution. In Campanella et al. (in press), participants discriminated the size of the intended object of a PD reach-to-grasp action when displays were in the egocentric perspective rather than allocentric, as in the present study. These issues are the subjects of further studies.

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