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Cues to intention: The role of movement information

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ABSTRACT

Body movement provides a rich source of cues about other people's goals and intentions. In the present research, we investigate how well people can distinguish between different social intentions on the basis of movement information. Participants observed a model reaching toward and grasping a wooden block with the intent to cooperate with a partner, compete against an opponent, or perform an individual action. In Experiment 1, a temporal occlusion procedure was used as to determine whether advance information gained during the viewing of the initial phase of an action allowed the observers to discriminate across movements performed with different intentions. In Experiment 2, we examined what kind of cues observers relied upon for the discrimination of intentions by masking selected spatial areas of the model (i.e., the arm or the face) maintaining the same temporal occlusion as for Experiment 1. Results revealed that observers could readily judge whether the object was grasped with the intent to cooperate, compete, or perform an individual action. Seeing the arm was better than seeing the face for discriminating individual movements performed at different speeds (natural-speed vs. fast-speed individual movements). By contrast, seeing the face was better than seeing the arm for discriminating social from individual movements performed at a comparable speed (cooperative vs. natural-speed individual movements, competitive vs. fast-speed individual movements). These results demonstrate that observers are attuned to advance movement information from different cues and that they can use such kind of information to anticipate the future course of an action.

1. Introduction

Perception of others' action is not simply a post-hoc reconstruction of the visual input, but an intrinsically predictive activity. When we observe the movements of other people, we cannot help but anticipate their future course. At the most basic level, from seeing the start of a movement, we can predict how it will end (Frith & Frith, 2006). For instance, by observing a person throwing a dart on a target board, we can predict the landing position of the dart on the board (Knoblich & Flach, 2001). Similarly, we can anticipate the depth of a volleyball or a tennis serve (Abernethy & Zawi, 2007; Abernethy, Zawi, & Jackson, 2008), predict the success of free shots at a basket (Aglioti, Cesari, Romani, & Urgesi, 2008), or determine whether a player is about to throw the ball or mimic a throw (Sebanz & Shiffrar, 2009). In more complex situations, predictive coding allows us to understand others' intentions and to predict what they will do next (Frith & Frith, 2006). For example, from seeing someone approaching her hand at a cup of coffee, we can anticipate not only the closing of her fingers on the handle, but the intention to drink.

A current controversy concerns the possibility to understand the intention of others by simply observing their movements (Jacob, 2008; Jacob & Jeannerod, 2005; Kilner, Friston, & Frith, 2007). It has been proposed that inferences regarding the intentions associated with a movement are made at the start of the movement and tested by

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predicting how the movement will continue (Wolpert, Doya, & Kawato, 2003). But is information from movement sufficient to make an inference regarding the intention associated with an action? Someone grasping a cup may grasp it to drink, to hand it to another person or to examine the cup itself. Is it possible to understand her intention by simply observing the start of her movement?

In the present research, we investigate how well people can distinguish between social and non-social intentions based on movement information. Specifically, we asked whether by observing the initial phase of a two-stage action, observers would be able to understand whether the movement was associated with a cooperative, competitive, or individual intent. Both cooperation and competition necessitate the ability to anticipate the action of the interacting partner. In cooperative situations, understanding the partner's intention might be important to optimally adapt to her action in service of a common goal (Sebanz, Bekkering, & Knoblich, 2006). In competitive situations, intention understanding might be equally important to prevent the other person's move in service of a conflicting goal (Ruys & Aarts, 2010).

We conducted two psychophysical experiments to determine how well observers can discriminate between cooperatively, competitively, and individually motivated actions under temporal and spatial occlusion conditions (Abernethy & Zawi, 2007). In Experiment 1, we used a temporal occlusion procedure to determine whether advance information picked up during the initial phase of the movement allowed observers to infer the model's intention. In Experiment 2, we examined what kind of cues observers relied upon for the detection of social intentions. This was done by masking selected spatial areas of the video clips representing the model's movement.

2. Experiment 1

In most daily life situations, grasping is the initial component of a broader action sequence in which the grasped object is used to achieve a desired goal. For instance, a cup might be grasped with the intention to drink or to clean up the table. It has been demonstrated that although the to-be-grasped object remains the same, movements performed with different end goals are characterized by different profiles of movement (Ansuini, Giosa, Turella, Altoè, & Castiello, 2008; Ansuini, Santello, Massaccesi, & Castiello, 2006; Becchio, Sartori, Bulgheroni, & Castiello, 2008a) controlled predominantly by the anterior parts of the motor system (Majdandzic et al., 2007; van Schie & Bekkering 2007). Similarly, differences in the reach-to-grasp kinematic patterning for the same object have been demonstrated depending on whether the grasped object is used to cooperate with a partner, compete against an opponent, or perform an individual action (Georgiou, Becchio, Glover, & Castiello, 2007; see also Becchio, Sartori, Bulgheroni, & Castiello, 2008b). Experiment 1 was designed to test whether these 'early' differences, already evident during the first step of a composite action, might constitute cues for discriminating between movements performed with different intents. Participant viewed video clips showing a model reaching toward and grasping a wooden block with different intents: cooperate with a partner as to build a tower, compete with an opponent as to put the object first on the middle of the working surface, or perform an individual action. We reasoned that if observers are sensitive to differences, which are detectable early on in an observed movement, and use these differences to sort through the different possibilities of intention, then they should be able to judge the model's intent by simply observing the initial reach-to-grasp phase of the action.

2.1. Method

2.1.1. Participants

Twenty participants (12 women and 8 men, ages 19–27 years) took part in the experiment. All participants reported normal or corrected-to-normal vision and were naive as to the purpose of the experiment. This research was approved by the University of Padua Ethical Committee in line with the Declaration of Helsinki.

2.1.2. Experimental stimuli

To create the stimulus material, we filmed four types of action sequences:

Single-agent: natural-speed. The model was requested to reach and grasp at a natural-speed the stimulus positioned in front of her right hand and bring it in the middle of the working surface.

Single-agent: fast-speed. The model was requested to reach and grasp as fast as possible the stimulus positioned in front of her right hand and bring it fast in the middle of the working surface.

Cooperation. Two models seated opposite to each other. They were requested to reach towards and grasp their respective objects and to cooperate as to build a tower in the middle of the working surface.

Competition. This action sequence was similar to the cooperative sequence except that the models had to compete as to put first the respective object in the middle of the working surface.

Actions were recorded from eight right-handed models (4 women and 4 men, ages 20–25 years). Each model performed 10 trials for each type of action. This resulted in 80 trials per type of action. Models were filmed from a lateral perspective using a digital video camera and recorded using a SMART-D motion analysis system (Bioengineering Technology & Systems, B|T|S|). Reflective passive markers (diameter: 0.25 cm) were attached to the wrist, index finger, and the thumb of the models' right hand. The wrist marker was used to measure the reaching component of the action. The markers positioned on the index finger and the thumb were used to measure the grasp component of the action. Six infrared cameras (sampling rate 140 Hz) placed around the table captured the movement of the markers in 3D space. Kinematic analysis was restricted to the reach-to-grasp movement phase, which was common to all action sequences. The statistical analysis considered key reach-to-grasp kinematic landmarks, which are known to vary depending on movement speed and the type of social attitude (for details see Becchio et al., 2008a; Becchio et al., 2008b; Georgiou et al., 2007; Sartori, Becchio, Bulgheroni, & Castiello, 2009). In line with previous studies (e.g., Becchio et al., 2008b), we found statistically significant differences among the four types of actions for nine kinematic parameters concerned with both the reaching and the grasping component of the action (see Table 1). Out of 320 trials, 30 representative trials for each type of action were selected. To uncover the structure of the possible differences related to the kinematics underlying the selected reach-to-grasp actions, we submitted the nine kinematic parameters to a principal components analysis (PCA). The results indicated that the first three components accounted for 79% of the variance (54%, 15%, and 10%, respectively). As they provided a good characterization of the data, they were retained and subjected to oblique rotation (direct oblimin).

Weights of the kinematic parameters for the first three components are reported in table Table 1. The three components were positively correlated with each another (rs from 0.21 to 0.32). The first component had positive weights ($\geqslant 0.30$) for movement time, the time of peak wrist deceleration and the amplitude of peak grip closing velocity. And negative weights for the amplitude of peak wrist velocity, the amplitude of maximum grip aperture, and the amplitude of peak grip opening velocity. This suggests that such component can be interpreted as a *global* descriptor of combined reaching and grasping kinematics. The time of grip opening velocity and the time of peak grip closing velocity weighted substantially on the second component, suggesting that it can be interpreted as a *grip timing* component. Finally, the third component showed only one large weight related to the amplitude of peak *wrist deceleration*.

Univariate ANOVAs (followed by Tukey HSD post-hoc tests) were used to compare the different type of actions ('cooperative', 'competitive', 'natural-speed' and 'fast-speed') with respect to the three kinematic components. The effect of the type of action was significant for all three components (see Table 2). For the global component, all pair-wise comparisons were significant. For the grip timing component, post-hoc comparisons showed significant differences between the natural-speed and the fast-speed movements, and between the cooperative and the competitive movements. This indicates that this component has the ability to discriminate between movements performed at different speeds. Finally, for the wrist deceleration component, pair-wise comparisons revealed significant differences between the fast-speed movements and both the competitive and the natural-speed movements. Because only the global kinematic component discriminated between the cooperative and the natural-speed movements it can be suggested that the kinematic profiles for cooperative vs. natural-speed movements were more similar compared to those for both cooperative vs. competitive movements (discriminated by the global component and the grip timing component) and competitive vs. fast-speed movements (discriminated by the global component and the wrist deceleration component).

Linear discriminant analysis on the component scores provided further support to this interpretation. Whereas 92% of competitive trials were correctly classified based on the three kinematic components, only 59% of cooperative trials were correctly classified as cooperative. Indeed, 30% of cooperative trials were misclassified as natural-speed trials, and 7% as competitive trials.

120 unique video clips, 30 per each type of action sequence (Avi format, disabled audio, 25 frames/s, resolution 720×576 pixel, bit rate 1200, aspect ratio 16:9, duration 3 s, subtended region $22.62° \times 33.40°$), were edited using a video editing software (Adobe Premiere pro). To ensure that only advance sources of information were made available to participants as to judge the model's intention, video clips were temporally occluded at the time the fingers contacted the object. Each video clip started therefore with the models resting their right hand on a starting pad and ended when the models closed their hands upon the object. Neither the second part of the movement nor the interacting model was made visually available (see Fig. 1).

2.1.3. Procedure

Testing was carried out in a sound-attenuated dimly lit room (luminance of 1.5 cd/m^2). Participants sat in front of a computer screen (background luminance of 0.5 cd/m^2), with their head positioned on a head-chin-rest so that the eye–screen distance was 50 cm. Stimuli-presentation timing and randomization procedures were controlled using E-Prime V2.0 software (Psychology Software Tools, Pittsburgh, PA). A trial started with the presentation of a fixation point (1000 ms), followed by the video clip depicting the reach-to-grasp phase of the action sequence (3000 ms). The task was to predict the type of action by pressing a key with the right or the left index finger.

Participants were instructed to respond as quickly as possible while keeping the number of errors low. The maximum time allowed to respond was 3000 ms. A feedback

Table 1
Weights of the kinematic parameters for the first three components.

	Component **1**	Component **2**	Component **3**
Movement time (ms)	0.721	0.286	0.203
Maximum wrist velocity (mm/s)	−0.776	−0.113	−0.132
Maximum wrist deceleration (mm/s^2)	0.016	−0.100	0.977
Time of maximum wrist deceleration (ms)	0.707	0.276	0.212
Maximum aperture (mm)	−0.889	0.161	0.292
Maximum opening velocity (mm/s)	−0.810	−0.122	−0.155
Maximum closing velocity (mm/s)	0.869	−0.109	−0.025
Time of maximum opening velocity (ms)	0.187	0.722	0.097
Time of maximum closing velocity (%)	−0.071	0.930	−0.137

Table 2
Kinematic differences across types of actions (average component scores).

	Omnibus ANOVA	Natural-speed vs. fast-speed	Cooperative vs. competitive	Competitive vs. fast-speed	Cooperative vs. natural-speed
Component 1 global	$F_{(3101)} = 118.764$ $p < 0.001$ $\eta_p^2 = 0.77$	1.203 vs. −0.651 $p < 0.001^{**}$	0.564 vs. −1.008 $p < 0.001^{**}$	−1.008 vs. −0.651 $p = 0.035^{*}$	0.564 vs. 1.203 $p < 0.001^{**}$
Component 2 grip timing	$F_{(3101)} = 5.629$ $p = 0.001$ $\eta_p^2 = 0.118$	0.320 vs. −0.380 $p = 0.040^{*}$	0.442 vs. −0.345 $p = 0.017^{*}$	−0.345 vs. −0.380 $p = 0.999$	0.442 vs. 0.320 $p = 0.967$
Component wrist deceleration	$F_{(3101)} = 48.052$ $p < 0.001$ $\eta_p^2 = 0.576$	0.364 vs. −1.210 $p < 0.001^{**}$	0.311 vs. 0.718 $p = 0.117$	0.718 vs. −1.210 $p < 0.001^{**}$	0.311 vs. 0.364 $p = 0.992$

* $p < 0.05$.
** $p < 0.001$.

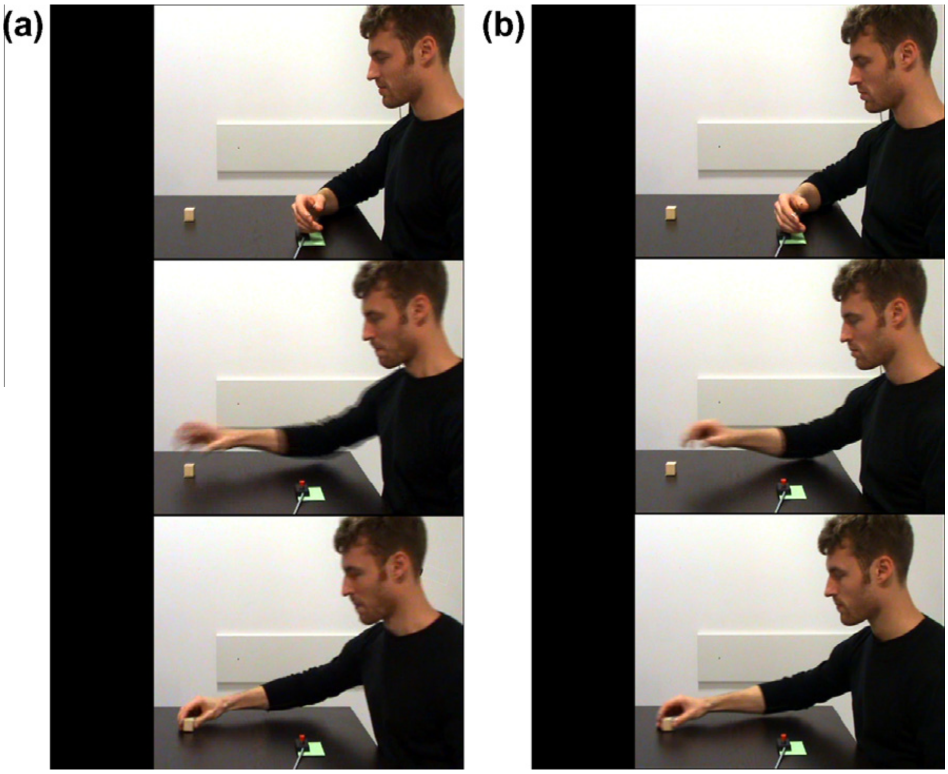

Fig. 1. Stimuli used in Experiment 1. Panel 'a'. Single frames extracted from a video clip representing a competitive action sequence. Panel 'b'. Single frames extracted from a video clip representing a cooperative action sequence.

was given in case of missed response (i.e., a response given after 3000 ms). The inter trial interval was 1000 ms.

Participants were tested in four experimental conditions:

1. *Natural-speed vs. fast-speed*. In this condition, participants were requested to judge whether the observed reach-to-grasp movement prepared for an individual action performed at either natural or fast-speed.
2. *Cooperative vs. competitive*. In this condition, participants were requested to judge whether the observed reach-to-grasp movement prepared for a cooperative or a competitive action.
3. *Competitive vs. fast-speed*. In this condition, participants were requested to judge whether the observed reach-to-grasp movement prepared for a competitive or an individual fast-speeded action.
4. *Cooperative vs. natural-speed*. In this condition, participants were requested to judge whether the observed reach-to-grasp movement prepared for a cooperative or an individual natural-speeded action.

60 trials were presented for each of the four conditions, for a total of 240 trials. The order of presentation for the four conditions and the type of trial within each condition were randomized across participants. The experimental session lasted about 30 min.

2.1.4. Data analysis

Missed responses were less than 0.3% and, therefore, they were not analyzed. Participants' performance was assessed by means of response times (RTs) and proportion of correct responses (accuracy). Response times were analyzed only for correct responses and were calculated from the time at which the model represented within the video clips started the action. As in *yes-no* tasks the proportion of correct responses represents a biased measure of accuracy (i.e., it does not consider systematic errors in performance), we also extracted Signal Detection Theory parameters (Heeger, 1997; Macmillan & Creelman, 2005). The proportion of hits (i.e., proportion of stimuli correctly detected when present) and false alarms (i.e., proportion of stimuli reported when not present) were used to calculate the location of the criterion *c* (i.e., the general tendency to respond *yes* or *no*; e.g., a value of 0 indicates neutral bias) and the *d'*, an unbiased sensitivity index independent of the criterion the participant is adopting (e.g., a value of 0 indicates an inability to distinguish signal from no signal, whereas larger values indicate a correspondingly greater ability to distinguish signal from noise). Before the *d'* and *c* calculation, the hit and false alarm proportions were corrected by adding 0.5 to both the number of hits and the number of false alarms and adding 1 to both the number of signal trials and the number of noise trials to avoid indeterminate values (loglinear approach; Hautus, 1995). Data from two participants were not included within the analyses for technical problems. RTs, accuracy, *d'* values and *c* values were submitted to separate ANOVAs with intention (natural-speed vs. fast-speed; cooperative vs. competitive; competitive vs. fast-speed; cooperative vs. natural-speed) as within-subjects factor. Bonferroni corrections were applied (alpha level 0.05). The level of *c* and *d'* were calculated for each condition and one-sample *t*-tests were performed to ascertain the participants' tendency to respond yes or no.

2.2. Results and discussion

Overall accuracy, collapsed across tasks, was 71%. The repeated-measure ANOVA on RTs yielded a statistically significant effect of intention [$F_{(3,51)} = 7.65$, $p < 0.001$, $\eta_p^2 = 0.31$]. Post-hoc comparisons revealed that RTs for the 'cooperative vs. natural-speed' condition were longer than those for the 'natural-speed vs. fast-speed', the 'cooperative vs. competitive' and the 'competitive vs. fast-speed' conditions (ps < 0.001; see Fig. 2a). The ANOVA on the pro-

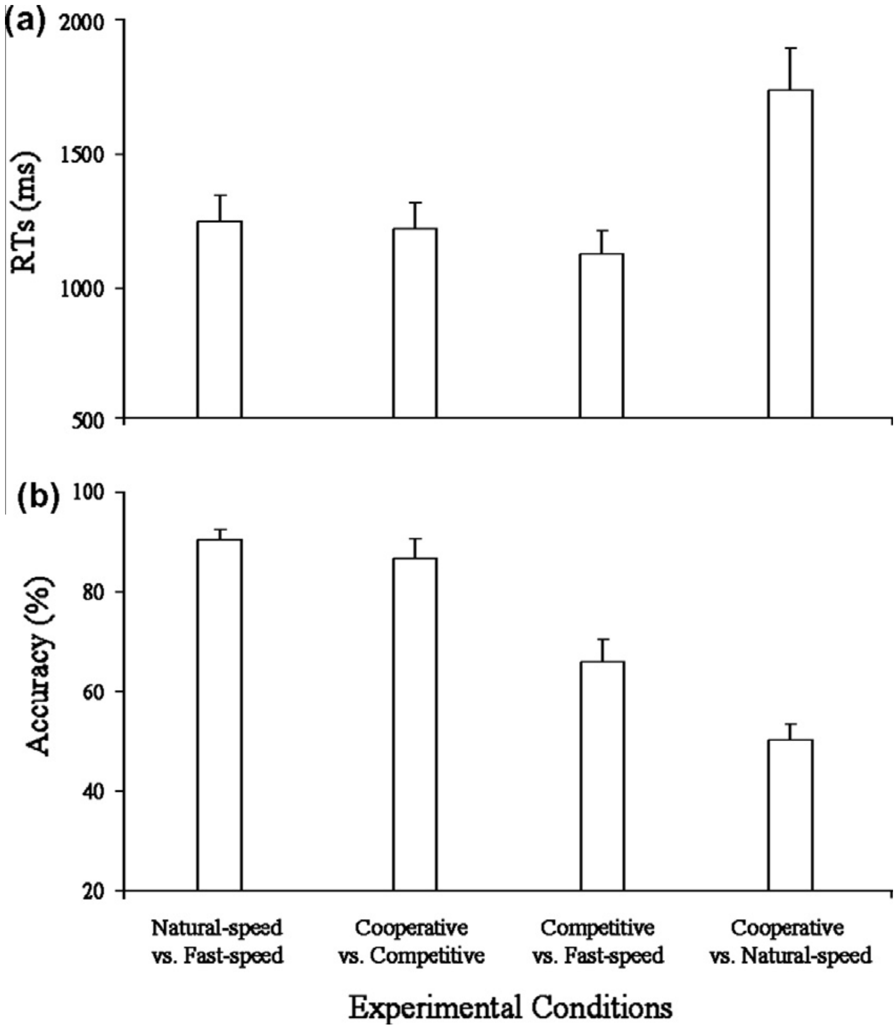

Fig. 2. Results for Experiment 1. Mean RTs (panel 'a') and accuracy values (panel 'b') across experimental conditions. Bars represent the standard error.

portion of correct responses yielded a similar pattern of results. That is, a statistically significant effect of intention [$F_{(3,51)} = 30.12$, $p < 0.001$, $\eta_p^2 = 0.64$] was found. Post-hoc comparisons indicated that the accuracy values were lower for the 'cooperative vs. natural-speed' condition than for the 'natural-speed vs. fast-speed', the 'cooperative vs. competitive' and the 'competitive vs. fast-speed' conditions (ps < 0.001; see Fig. 2b). Furthermore, accuracy values were lower for the 'competitive vs. fast-speed' condition than for the 'natural-speed vs. fast-speed' and the 'cooperative vs. competitive' conditions (ps < 0.001). The ANOVA on *c* revealed that the main factor of intention was not significant [$F_{(3,51)} = 1.04$, $p = 0.39$, $\eta_p^2 = 0.05$]. One-sample *t*-tests performed to ascertain the participants' tendency to respond yes or no revealed that for the 'competitive vs. fast-speed' condition, *c* values did not differ from 0 (ps > 0.05). For the 'natural-speed vs. fast-speed' condition, the value of *c* was significantly lower than 0 [$t_{(17)} = -3.232$; $p < 0.05$], thus suggesting a bias towards judging fast-speed actions as natural-speed actions. For the 'cooperative vs. competitive' and the 'cooperative vs. natural-speed' conditions, *t*-tests revealed a marginally significant bias towards judging competitive and natural-speed actions as cooperative [respectively, $t_{(18)} = -1.858$; $p = 0.080$; $t_{(18)} = -1.900$; $p = 0.074$]. For *d'*, the ANOVA yielded a significant main effect of intention [$F_{(3,51)} = 61.89$, $p < 0.001$, $\eta_p^2 = 0.43$]. Post-hoc comparisons confirmed that sensitivity for the 'cooperative vs. natural-speed' condition was significantly lower than that for the 'natural-speed vs. fast-speed', the 'cooperative vs. competitive' and the 'competitive vs. fast-speed' conditions (ps < 0.001). Furthermore, sensitivity was lower for the 'competitive vs. fast-speed' condition than for the 'natural-speed vs. fast-speed' and the 'cooperative vs. competitive' conditions (ps < 0.001; see Fig. 3). *d'* values were significantly greater than 0 for the 'natural-speed vs. fast-speed' [$t_{(17)} = 25.97$, $p < 0.001$], the 'cooperative vs. competitive' [$t_{(17)} = 10.15$, $p < 0.001$] and the 'competitive vs. fast-speed' conditions [$t_{(17)} = 4.07$, $p < 0.001$]. For the 'cooperative vs. natural-speed' condition, *d'* value was not significantly different from 0 [$t_{(17)} = -0.707$, $p = 0.49$].

These findings demonstrate that by simply observing the initial phase of a two-stage action, participants were able to discriminate between individual natural and fast-speed movements, cooperative and competitive movements, competitive and individual fast-speeded movements. For the 'cooperative vs. natural-speed' condition discrimination performance was at chance level. In line with results from the linear discriminant analysis, this suggests that discrimination between cooperative and natural-speed movements was more difficult than discrimination between the other types of movements.

3. Experiment 2

Results from Experiment 1 suggest that observers have the ability to pick up and use advance information as to judge the intent associated with a specific movement. However, it remains unclear to which specific source of information observers rely upon as to discriminate between movements associated with different intentions. To explore this issue here we used a spatial occlusion procedure. Visibility to selected spatial areas of the model's movement was masked so that either the models' forearm and hand ensemble or the face was visually available to participants. If the ability to anticipate the outcome of the observed action is reduced when a specific body part is occluded, then the occluded visual cue should play a role in such endeavour.

3.1. Method

3.1.1. Participants

Twenty students (11 women and 9 men, ages 21–36 years) took part in the experiment. All participants reported normal or corrected-to-normal vision and were naive as to the purpose of the experiment. None of them had participated in the previous experiment.

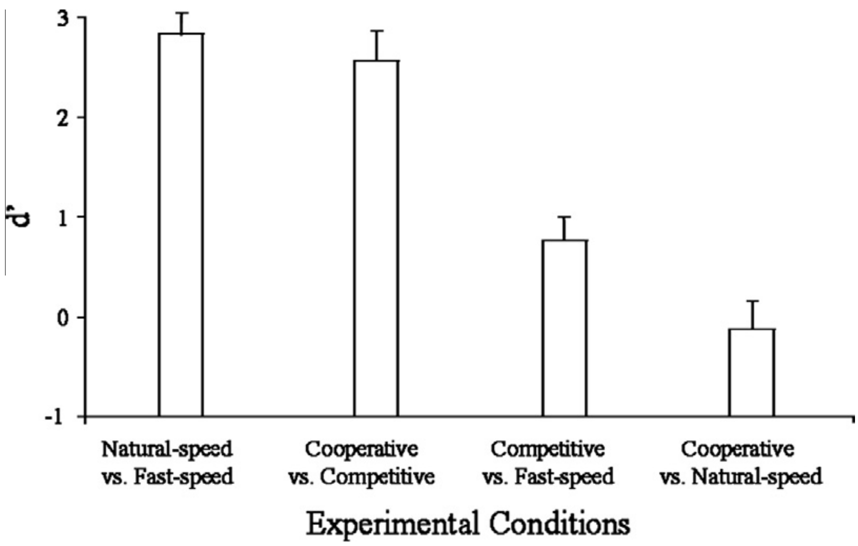

Fig. 3. Results for Experiment 1. *d'* values across experimental conditions. Bars represent the standard error.

3.1.2. Experimental stimuli

Stimuli were created by masking selected spatial areas of the model's movement. Digital video editing was used to produce independent spatial occlusion of (i) the upper part of the model's body (from shoulders to head; i.e., 'arm' video clips) and (ii) the lower part of the model's body (from shoulders to arm and forearm; i.e., 'face' video clips). For each level of spatial occlusion, 120 video clips, 30 per each type of action sequence, were edited. As for Experiment 1, all trials were also temporally occluded at the time the fingers contacted the object. Neither the second part of the movement nor the interacting model was made visually available.

3.1.3. Procedure

This was the same as for Experiment 1, except that two blocks of trials were presented. In one block, only 'face' video clips were presented. In the other block, only 'arm' video clips were presented. The order of blocks was counterbalanced across participants. The experimental session lasted approximately 50 min.

3.1.4. Data analysis

Missed responses were less than 0.4% and, therefore, they were not analyzed. Participants' performance was assessed by means of correct response times (RTs) and proportion of correct responses (accuracy). The proportions of hits and false alarms were used to calculate the criterion *c* and the signal detection index *d'*. Data from one participant were not included within the analyses for technical problems. RTs, accuracy, *d'* values and *c* values were submitted to separate ANOVAs with intention (natural-speed vs. fast-speed; cooperative vs. competitive; competitive vs. fast-speed; cooperative vs. natural-speed) and type of spatial occlusion ('face' video clips, 'arm' video clips) as within-subjects factor. Bonferroni corrections were applied (alpha level 0.05).

3.2. Results and Discussion

Overall accuracy, collapsed across tasks, was 72% (73% for the 'face' videos and 71% for the 'arm' videos). The repeated-measure ANOVA on RTs yielded a significant interaction of intention by type of spatial occlusion

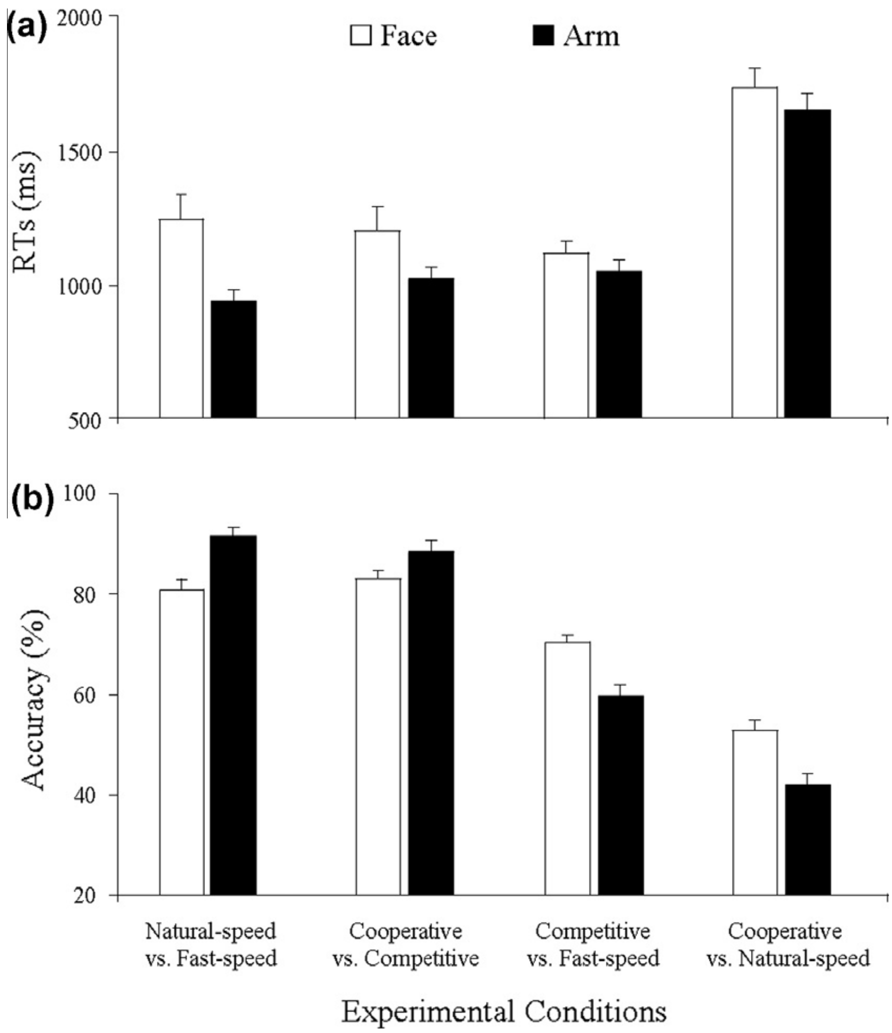

Fig. 4. Results for Experiment 2. Mean RTs (panel 'a') and accuracy values (panel 'b') across experimental conditions for 'face' (white bars) and 'arm' (black bars) video clips. Bars represent the standard error of means.

[$F_{(3,54)} = 3.23$, $p < 0.05$, $\eta_p^2 = 0.15$]. Post-hoc comparisons showed that for both levels of spatial occlusion, RTs were slower for the 'cooperative vs. natural-speed' condition than for the remaining conditions (ps < 0.001; see Fig. 4a). Further, for the 'natural-speed vs. fast-speed' condition and for the 'cooperative vs. competitive' condition, RTs were slower for the 'face' than for the 'arm' video clips (ps < 0.05; see Fig. 4a). Similarly, the ANOVA on the proportion of correct responses revealed a significant interaction of intention by type of spatial occlusion [$F_{(3,54)} = 14.57$, $p < 0.001$, $\eta_p^2 = 0.45$]. Post-hoc contrasts showed that for both levels of spatial occlusion, the proportion of correct responses was significantly different across the four experimental conditions (ps < 0.05, see Fig. 4b). Further, for the 'natural-speed vs. fast-speed' condition, the accuracy level was lower for the 'face' than for the 'arm' video clips ($p < 0.05$; see Fig. 4b). For the 'cooperative vs. competitive' condition the accuracy level was slightly lower for the 'face' than for the 'arm' video clips ($p < 0.05$; see Fig. 4b). For the 'competitive vs. fast-speed' condition and for the 'cooperative vs. natural-speed' condition, the proportion of correct responses was higher for the 'face' than for the 'arm' video clips (ps < 0.05; see Fig. 4b). The ANOVA on *c* failed to show a significant effect of either intention [$F_{(3,54)} = 2.01$, $p > 0.05$, $\eta_p^2 = 0.10$], spatial occlusion [$F_{(1,18)} = 0.76$, $p > 0.05$, $\eta_p^2 = 0.005$] or interaction [$F_{(3,54)} = 1.35$, $p > 0.05$, $\eta_p^2 = 0.06$]. One-sample *t*-tests performed to ascertain the participants' tendency to respond yes or no revealed that for the 'cooperative vs. competitive' and the 'cooperative vs. natural-speed' conditions, the value of *c* was significantly lower than 0 (ps < 0.05), thus suggesting a tendency to judge as cooperative both competitive and natural-speed movements. Similarly, the value of *c* was significantly lower than 0 ($p < 0.05$) for the 'natural-speed vs. fast-speed' condition. The ANOVA on *d'* yielded a significant interaction of intention by spatial occlusion [$F_{(3,54)} = 15.25$, $p < 0.001$, $\eta_p^2 = 0.50$]. Post-hoc comparisons confirmed that sensitivity for the 'cooperative vs. natural-speed' condition was significantly lower compared to the remaining conditions (ps < 0.001; see Fig. 5). Furthermore, sensitivity was significantly lower for the 'competitive vs. fast-speed' condition than for the 'natural-speed vs. fast-speed' condition and the 'cooperative vs. competitive' condition (ps < 0.001). In terms of spatial occlusion, for the 'competitive vs. fast-speed' condition and for the 'cooperative vs. natural-speed' conditions, sensitivity was significantly higher for the 'face' than for 'arm' video clips (ps < 0.05; see Fig. 5). In contrast, for the 'natural-speed vs. fast-speed' condition, sensitivity was lower for the 'face' than for the 'arm' video clips ($p < 0.001$; see Fig. 5). For the 'cooperative vs. competitive' condition, no difference in sensitivity was observed between 'face' and the 'arm' video clips, suggesting that despite the slight statistical difference in accuracy level (see above), 'face' and 'arm' cues were equally informative in discriminating between cooperative and competitive movements.

These results bring to two conclusions. First, in judging the intention of a model grasping an object, observers are able to pick up advanced information from different cues. Regardless of the level of spatial occlusion (i.e., face or arm), discrimination was most accurate for 'natural-speed vs. fast-speed' actions and 'cooperative vs. competitive' actions, less accurate for 'competitive vs. fast-speed' actions, and least accurate for 'cooperative vs. natural-speed' actions. Second, face cues and arm cues are not equally informative with respect to the different experimental conditions. For the 'natural-speed vs. fast-speed' condition, discrimination was faster and more accurate for the 'arm' than for the 'face' video clips, suggesting that in such circumstances 'arm' cues were more informative than 'face' cues. For the 'competitive vs. fast-speed' and the 'cooperative vs. natural-speed' conditions, discrimination performance was better for the 'face' than for the 'arm' video clips, therefore suggesting that in such circumstances 'face' cues were more informative than 'arm' cues.

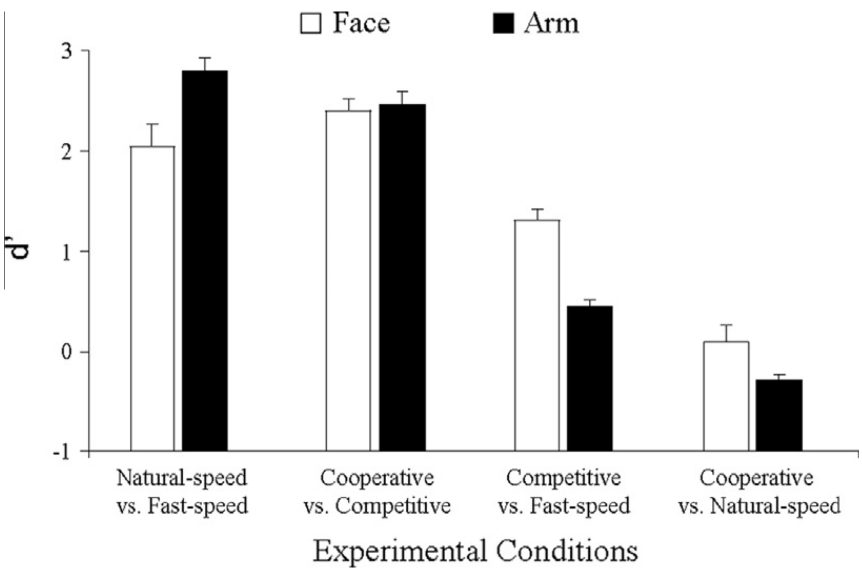

Fig. 5. Results for Experiment 2. *d'* values across experimental conditions for the 'face' (white bars) and the 'arm' (black bars) video clips. Bars represent the standard error of means.

3.2.1. Comparison analyses

To compare discrimination performance from 'full-body' video clips with discrimination performance from 'face' and 'arm' video clips, we run a mixed design ANOVA on *d*' values with Experiments (1, 2) as a between-subjects factor and intention (natural-speed vs. fast-speed; cooperative vs. competitive; competitive vs. fast-speed; cooperative vs. natural-speed) as a within-subjects factor. Results confirmed the significant effect of intention [$F_{(3,96)} = 84.83$, $p < 0.001$]. By contrast, the interaction was not significant [$F_{(3,96)} = 0.59$, $p > 0.05$], suggesting that the different amount of visually available information had no substantial impact on the accuracy of discrimination performance.

4. General discussion

A fundamental prerequisite for successful social interaction is the ability to understand the intentions of others. The better we can understand another person's intention, the more successful our interactions with that person will be (Frith, 2007). In real-life social interactions, multiple cues to intentions are often available: observers can rely – among other cues – on information gathered from the context, as well as on pre-existing contextual information, including information derived from previous experience with the person involved (Beer & Ochsner, 2006; Zaki & Ochsner, 2009). Our results provide the first evidence that, in the absence of contextual cues, movement cues can be used to discriminate between social and non-social intentions.

When presented with body movements, people not only can judge the types of performed action (Dittrich, 1993; Vanrie & Verfaillie, 2004), but they can also determine the actor's identity (e.g., Cutting & Kozlowski, 1977; Loula, Prasad, Harber, & Shiffrar, 2005), gender (e.g., Brooks et al., 2008; Kozlowski & Cutting, 1977; Pollick, Lestou, Ryu, & Cho, 2002; Troje, 2002), and age (Montepare & Zebrowitz-McArthur, 1988). Furthermore, from observing day-to-day movements such as drinking or lifting a box, observers can easily recognize the actor's emotions (Pollick, Paterson, Bruderlin, & Sanford, 2001), expectations (Runeson & Frykholm, 1983) and deceptive intentions (Grezes, Frith, & Passingham, 2004; Sebanz & Shiffrar, 2009). For example, observers are able to judge whether in a lifting a box task an actor is attempting to deceive them regarding the real weight of the box (Grezes et al., 2004). Our findings critically extend this literature by showing that advance information gained during the viewing of the initial phase of an action sequence allows observers to discriminate across movements performed with different social intentions.

4.1. When seeing the face is better than seeing the arm

Making correct inferences regarding the imminent cooperative/competitive behaviours of others has adaptive benefits and might be crucial for survival. Our findings indicate that advance information from movement is sufficient to distinguish between these two basic modes of social interaction solely on motion patterns. From seeing another person reaching towards an object and grasping it, participants could readily judge whether the object was grasped with the intent to cooperate with a partner, compete against an opponent, or perform an individual action.

What kind of cues did observers rely upon? Results from Experiment 2 indicate that 'arm' cues were more informative than 'face' cues for discriminating between natural-speed and fast-speed movements. By contrast, 'face' cues were more informative than 'arm cues' for discriminating between cooperative and natural-speed movements, and between competitive and fast-speed movements. Natural and fast individual movements are performed at different speeds. Since speed information is conveyed by 'arm' cues, but not by 'face' cues, this might well explain why discrimination performance was better for the 'arm' than for the 'face' video clips.

By contrast, seeing the face might be better than seeing the arm when the task requires to discriminate between social and individual movements performed at a comparable speed. The processing of the orientation of faces in general and of eye gaze in particular is thought to play a critical role in social attention, i.e. signalling the direction of another individual's attention (Allison, Puce, & McCarthy, 2000; Frischen, Bayliss, & Tipper, 2007; Nummenmaa & Calder, 2009). From observing another person's gaze direction, we can infer what she might be interested in or what she might desire (Lee, Eskritt, Symons, & Muir, 1998) and, consequently, what she might want to do next (Castiello, 2003; see also, Pierno et al., 2006; Pierno, Mari, Glover, Georgiou, & Castiello, 2006). In social contexts, gaze direction might provide an immediate cue to discriminate whether two agents are acting on a shared goal or on individual purposes (Pierno, Becchio, Turella, Tubali, & Castiello, 2008). The finding that 'face' cues were more informative than 'arm cues' for discriminating cooperative vs. natural-speed movements and competitive vs. fast-speed movements adds evidence to this notion, suggesting that cooperative and competitive intention might be read from 'face' cues. Future studies will be necessary to determine the specific facial cues exploited by observers. Whereas gaze orientation appears as the most likely candidate, other cues such as head orientation and head movement (e.g., head tilts) might be used.

4.2. A cooperation bias?

For both full-body video clips (Experiment 1) and partially masked video clips (Experiment 2), we found a bias towards reporting cooperation in both the 'cooperative vs. competitive' and the 'cooperative vs. natural-speed' conditions. How should this pattern of results be interpreted? An intriguing possibility is that the lower criterion for the 'cooperative vs. competitive' and the 'cooperative vs. natural-speed' conditions reflects a tendency to interpret as cooperative actions performed with a competitive or individual intent, i.e. to perceive as cooperative actions performed with a non-cooperative intent. Cooperation has been proposed as a distinctive trait of human cognition: whereas primate cognition in general is driven mainly by social competition, the unique aspects of human cognition are driven by, or even constituted by, social cooperation (Moll & Tomasello, 2007). Differently from other primates, humans show a natural propensity towards cooperation. From an early age human infants and young children are naturally altruistic, helpful, and informative (Warneken & Tomasello, 2009). Cooperation is observed in the total absence of material reward and, in contrast to a purely economic perspective, tends to be maintained even when immediate and tangible pay-offs are insufficient or sub-optimal (Schuster & Perelberg, 2004). In line with these findings, we speculate that over-attribution of cooperative intention might reflect a *cooperation bias*, influenced by intrinsic reinforcements evoked by interaction with another human being (Schuster & Perelberg, 2004). In this interpretation, discriminating between cooperative movements and individual natural-speed movements might be more difficult than discriminating between competitive movements and fast-speed movements not only because of the similarity of the kinematics profiles, but also because observers are naturally inclined to see cooperation even when no cooperation does exists.

4.3. Grasping social intentions

Is it possible to understand social intentions from movement observation? Our findings have two limitations in answering this question. First, because participants were tested in a *yes-no task*, the present findings do not allow to conclude that advance information from movement is sufficient to infer social intentions. In a yes-no task, participants are required to choose one of two alternative responses. Future studies, employing different paradigms, are needed to clarify whether social intentions might be correctly identified from motion patterns when the number of possible intentional actions is larger.

Second, our results do not provide information regarding the mechanisms involved in intention-from-motion judgement. It has been proposed that an important function of the motor system lies in the prediction of others' actions (Blakemore & Frith, 2005; Prinz, 2006; Wilson & Knoblich, 2005). Observing others' actions activates corresponding representations in the observer's motor system and these representations might be used to generate predictions by running internal simulations. In this perspective, the same predictive mechanism used to anticipate the sensory consequences of one's own movement may be employed to predict what others will do next (Wolpert & Flanagan, 2001). One possibility is thus that in the present study participants relied on simulation processes in their own motor system to anticipate the actor's social intention in grasping the object. Another possibility, as discussed by Giese and Poggio (2003), is that intention-from-movement judgements relied on purely perceptual processes, not involving the motor system. Functional MRI and TMS studies may help to decide between these two possibilities by clarifying the role of motor system in processing advanced movement information.

The central advance of this study is the demonstration that observers (i) are attuned to advance movement information from different cues and (ii) can use this information to discriminate between arm movements performed with different social intents. These findings have direct implications for theories of action representation as they suggest that intention attribution is sensitive to kinematic constrains. Because different intentional actions have different motion signatures, observers can rely on early differences in kinematics to estimate intention from movement observation.

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