RESEARCH ARTICLE

Cooperation or competition? Discriminating between social intentions by observing prehensile movements

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Abstract Body movement provides a rich source of information about other people's goals and intentions. In the present study, we examined a particular aspect concerned with the interpretation of bodily movement—how well people can distinguish between different social intentions by observing a reach-to-grasp movement. To ascertain to what extent intention-from-motion judgements rely on visual kinematics, we compared prediction performance on a typical temporal-occlusion video task with prediction performance on a temporal-occlusion point-light task. In the video task, participants observed videos showing a model reaching towards and grasping a wooden block with different intents: to cooperate with a partner in building a tower, compete with an opponent to be the first to put the object in the middle of the working surface, or perform an individual action. In the point-light task, participants observed point-light displays of the same movements. Although predictions were more accurate for the video task, prediction performance was not disrupted for the point-light task, suggesting that essential kinematic information available in point-light displays was indeed sufficient for intention-from-motion judgement. Importantly, the same kinematic landmarks were used to discriminate between social intentions for the video and the point-light task. This suggests that observers not only have the ability to use kinematic information when no other information is available, but they use kinematic information to discriminate between intentions when watching the motion of others under full light conditions.

Keywords Cooperation · Competition · Kinematics · Intention · Point-light · Discrimination of intention · Prehensile movement

Introduction

As social animals, humans behave largely on the basis of their interpretations and predictions about the actions and intentions of others. On encountering others, the ability to determine what the other person is like and what she is going to do next is essential for successful social interaction (Frith and Frith 2006). Who goes there? What are the other person's intentions? Does she intend to help me or harm me?

An important source of information for answering these questions is bodily movement. When presented with body movements, people can not only judge the type of actions performed (Dittrich 1993; Vanrie and Verfaillie 2004), but also the associated emotions (Atkinson et al. 2004; Clarke et al. 2005; Dittrich et al. 1996; Pollick et al. 2001, 2002). Bodily movements can also provide information regarding the future course of ongoing actions. For example, by observing a person aiming a dart at a target board, observers can predict the landing position of the dart on the board (Knoblich and Flach 2001). Depending on their level of motor skill, they might be able to anticipate the direction and depth of a badminton or a tennis stroke (Abernethy

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et al. 2001, 2008 Abernethy and Zawi 2007; Shim et al. 2005) or to determine whether a basketball player is about to throw a ball or mimic a throw (Sebanz and Shiffrar 2009). Similarly, people viewing everyday actions such as lifting a box might be able to judge from the actor's motion whether he is trying to deceive them concerning the real weight of the box (Grezes et al. 2004; Runeson and Frykholm 1983).

An important tenet stemming from this body of research is that, in some circumstances, the movement of a human body or body part is sufficient to make judgements not only regarding fundamental movement patterns, but also in relation to the actor's intention. In the present study, we examined a particular aspect of intention-from-motion judgement—how well people can distinguish between different social intentions by observing a reach-to-grasp movement.

The way we reach towards an object and grasp it varies depending on how we want to use that object (Ansuini et al. 2006; Becchio et al. 2008a). Grasping kinematics for the same object—a bottle, for example—varies depending on what the actor intends to do with the object: throw it, pour something from it, or pass it to another person (Ansuini et al. 2008). Similarly, the kinematics of reach-to-grasp movements depends on the actor's social intention: to cooperate with a partner, compete against an opponent, or perform an individual action (Georgiou et al. 2007; see also Becchio et al. 2008b).

An important, but so far poorly investigated question is whether observers are sensitive to the kinematic properties of prehensile movements, and can use these properties to discriminate between movements performed with different intentions. Experimentally, one approach to this issue is to present temporally occluded video clips of arm movements (Abernethy and Zawi 2007; Sartori et al. 2011). Sartori and colleagues (2011) adopted this approach to investigate how well people can distinguish between different social intentions by observing prehensile movements. Participants observed a model reaching towards and grasping a wooden block with the intent to cooperate with a partner, compete against an opponent, or perform an individual action. The results revealed that observers could readily judge the intention of the model by observing the initial reach-to-grasp phase of the movement. Similar results were obtained for full-body video clips and partially masked video clips, displaying only the arm and forearm of the model.

In the present study, we aimed to isolate the specific role that visual kinematics might play in discriminating between intentions. Video clips have the advantage of capturing the normal visual input that is available when watching the motion of others. However, because movement information is provided in conjunction with other sources of informa-tion, one limitation of video clips is that they do not provide a direct means for determining the specific contribution of kinematics. To ascertain to what extent intention-from-movement judgements rely on visual kinematics, we compared prediction performance on a typical temporal-occlusion video task with prediction performance on a temporal-occlusion point-light task. In the video task, participants observed videos showing a model reaching towards and grasping a wooden block with different intents: to cooperate with a partner in building a tower, compete with an opponent to be the first to put the object in the middle of the working surface, or perform an individual action. In the point-light task, participants observed point-light displays of the same movements consisting of disconnected moving dots representing the location of the wrist, the index finger, and the thumb of the model's right hand. Point-light displays are devoid of all the contours, textures, shapes, colours and figural cues that exist in film displays, but preserve the essential kinematic information characterizing the observed movement pattern. We reasoned that, if observers rely on kinematic information to discriminate between intentions in grasping an object, then: (i) observing prehensile movements under point-light conditions should not disrupt prediction performance; (ii) prediction performance should be related to the kinematic properties of the observed movements.

Method

Participants

Twenty undergraduate and graduate students from the University of Padova (12 women and 8 men; mean age = 24.1 years, age range = 18–31 years) took part in the experiment. All had normal or corrected to normal vision and were naive as to the purpose of the experiment. This research was approved by the local Ethical Committee in line with the Declaration of Helsinki.

Materials

Video recording and motion capture

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

> *Single-agent*: *natural speed*. The model was asked to reach and grasp the stimulus positioned in front of his/her right hand, at natural speed, and move it to the middle of the working surface.
>
> *Single-agent*: *fast speed*. The model was asked to reach and grasp the stimulus positioned in front of his/her

right hand, as fast as possible, and move it quickly to the middle of the working surface.

Cooperation. The model was seated opposite an interacting partner. The model and the partner were asked to reach towards and grasp their respective objects, and cooperate to build a tower in the middle of the working surface.

Competition. This action sequence was similar to the cooperative sequence except that the model and the interacting partner had to compete to be the first to put first the respective object in the middle of the working surface.

We recorded the actions of eight right-handed models (4 women and 4 men, aged 20–25 years). To optimize the view of both the reaching and grasping components of the action, the actions were filmed from a lateral perspective using a digital video camera, and recorded using a SMART-D motion analysis system (Bioengineering Technology and Systems, B|T|S|). Reflective passive markers (diameter: .25 cm) were attached to the wrist, index finger and thumb of the model's right hand. The wrist marker was used to measure the reaching component of the action. The markers positioned on the index finger and 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. Each model performed 10 trials for each type of action. This resulted in a total of 80 trials per type of action. 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 Georgiou et al. 2007; Becchio et al. 2008a, b; Sartori et al. 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 grasping components of the action (see Table 1). Out of 320 trials, 30 trials were randomly selected for each type of

action (excluding trials with large amounts of missing data). 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 characterisation 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 1. The three components were positively correlated with each other (*R*s ranging from .21 to .32). The first component had positive weights (≥.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 peak grip opening velocity and the time of peak grip closing velocity weighted substantially on the second component, suggesting that this 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 types 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

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

	Component 1	Component 2	Component 3
Movement time (ms)	.721	.286	.203
Max wrist velocity (mm/s)	−.776	−.113	−.132
Max wrist deceleration (mm/s^2)	.016	−.100	.977
Time of max wrist deceleration (ms)	.707	.276	.212
Max aperture (mm)	−.889	.161	.292
Max opening velocity (mm/s)	−.810	−.122	−.155
Max closing velocity (mm/s)	.869	−.109	−.025
Time of max opening velocity (ms)	.187	.722	.097
Time of max closing velocity (%)	−.071	.930	−.137

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

	Omnibus ANOVA	Natural speed versus Fast speed	Cooperative versus competitive	Competitive versus fast speed	Cooperative versus natural-speed
Component 1 global	$F_{(3,101)} = 118.764$ $P < .001$ $\eta_p^2 = .77$	1.203 versus −.651 $P < .001$[**]	.564 versus −1.008 $P < .001$[**]	−1.008 versus −.651 $P = .035$[*]	.564 versus 1.203 $P < .001$[**]
Component 2 grip timing	$F_{(3,101)} = 5.629$ $P = .001$ $\eta_p^2 = .118$	.320 versus −.380 $P = .040$[*]	.442 versus −.345 $P = .017$[*]	−.345 versus −.380 $P = .999$	.442 versus .320 $P = .967$
Component wrist deceleration	$F_{(3,101)} = 48.052$ $P < .001$ $\eta_p^2 = .576$	.364 versus −1.210 $P < .001$[**]	.311 versus .718 $P = .117$	.718 versus −1.210 $P < .001$[**]	.311 versus .364 $P = .992$

* $P < .05$; ** $P < .001$

Fig. 1 Examples of stimuli used in the experiment. **a** Single frames extracted from a video clip representing a cooperative action sequence. **b** Single frames extracted from a point-light clip representing the same cooperative action sequence
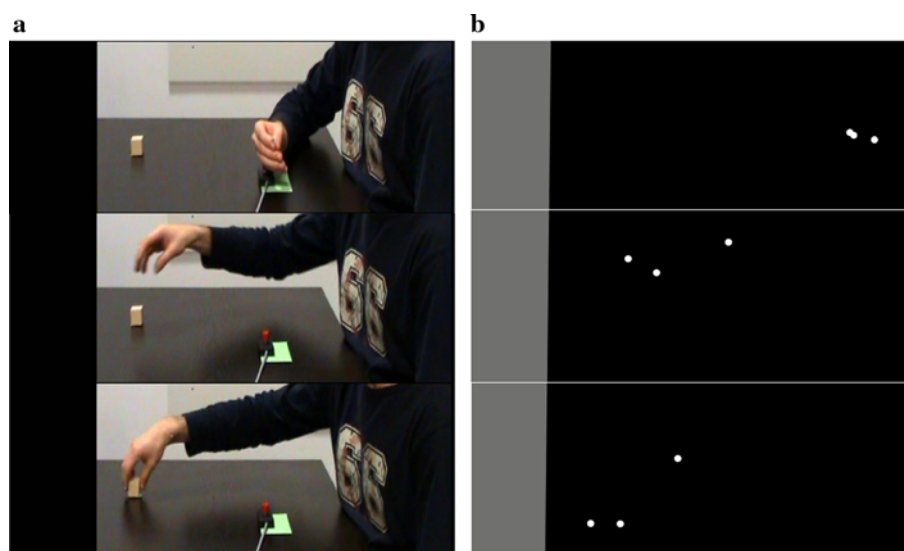
competitive and the natural-speed movements. The fact that only the global kinematic component discriminated between the cooperative and the natural-speed movements might suggest that the kinematic profiles for cooperative versus natural-speed movements were more similar compared to those for both cooperative versus competitive movements (discriminated by the global component and the grip timing component) and competitive versus fast-speed movements (discriminated by the global component and the wrist deceleration component).

Experimental stimuli

The videos and motion capture data corresponding to the selected trials (30 for each condition) provided the material used to prepare the video and point-light displays.

Video stimuli. 120 unique video clips, 30 for each type of action sequence (.avi format, disabled audio, 25 frames/ s, resolution 720 × 576 pixel, duration three s, subtended region 22.62° × 33.40°), were edited using a video editing

software (Adobe Premiere pro). Each video clip started with the models resting their right hand on a starting pad and ended right after the model had placed the object in its final position. To reduce movement onset predictability, the hand action started randomly 10, 18 or 25 frames after the video clip onset. Digital video editing was used so that only the region of the model's body comprising the shoulders to arm and forearm was visually available (see Fig. 1a). To ensure that only advanced sources of information were made available to participants in order to judge the model's intention, the video clips were temporally occluded at the point of contact between the fingers and the object, so that the hand disappeared behind a black screen after the reach-to-grasp movement. Neither the second part of the movement nor the interacting model was made visually available.

Point-light stimuli. To create point-light stimuli, 3D coordinates of the three markers used for motion acquisition (indicating the wrist, index finger, and the thumb of the model's right hand) were extracted for each trial. Data were

resampled to 25 frames/s, and coordinates were imported in 3D Studio MAX (Autodesk 2008) as moving bright spheres. Some manual smoothing was performed to avoid any 'jumpy' dot movements. To create the final point-light stimuli, all the frames of each action were rendered as .avi files (resolution 720 × 576 pixel, duration three s, subtended region 22.62° × 33.40°), with the white markers displayed against a black background. As in the video stimuli, the actions were displayed from a lateral perspective. An orthographic projection was used, and there was no occlusion, thus no explicit depth cues were available. Each video clip started with the model resting her hand on a starting pad and ended right after the model had placed the object in its final position. The action started randomly 10, 18 or 25 frames after the video clip onset. To ensure that the same amount of movement was available in the video and point-light stimuli, hand markers disappeared behind a grey screen at the end of the reach-to-grasp movement. The object grasped by the actor was not visible in the point-light animations (see Fig. 1b).

Procedure

Testing was carried out in a dimly lit room. Participants sat in front of a 17-inch computer screen, at a viewing distance of 60 cm. Stimuli presentation, timing and randomisation procedures were controlled using E-Prime V2.0 software (Psychology Software Tools, Pittsburgh, PA).

Each trial started with the presentation of a fixation point (1,800 ms), followed by the video (or point-light) clip depicting the reach-to-grasp phase of the action sequence (3,000 ms). The task consisted of predicting the type of action by pressing a key with the right or left index finger. Response keys were randomised across participants. The participants were instructed to respond correctly as quickly as possible and within a maximum of 6,000 ms. Feedback was given in case of a missed response (i.e. a response given after 6,000 ms). The inter-trial interval was 1,800 ms. Participants were tested in four experimental conditions for both the video and point-light tasks:

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

4. *Cooperative versus natural speed*. In this condition, participants were asked to judge whether the observed reach-to-grasp movement prepared for a cooperative or an individual action at natural speed.

To avoid the possibility of intention-from-motion judgement under full light conditions influencing judgement under point-light conditions, video stimuli and point-light stimuli were shown in two separate sessions, with a 10-min pause in between. The order of presentation of the sessions was counterbalanced across participants. Sixty trials were presented for each of the four conditions (for both the video and the point-light sessions), for a total of 480 trials. The order of presentation of the four conditions and the type of trial within each condition were randomised across participants. The experiment lasted about 50 min.

Data analysis

Missed responses accounted for less than .1% and were therefore not analysed. Participants' performance was assessed by means of response times (RTs) and proportion of correct responses (accuracy). Response times were only analysed for correct responses. Since 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 and Creelman 2005). The proportions of hits (i.e. the proportion of 'signal' responses on signal trials) and false alarms (i.e. the proportion of 'signal' responses on no-signal trials) were used to calculate the location of the criterion c (i.e. the general tendency to respond *signal* or *no signal*; e.g. a value of zero indicates no bias) and the d', an unbiased sensitivity index independent of the criterion adopted by the participant (e.g. a value of zero indicates an inability to discriminate between signal and no signal, whereas larger values indicate a correspondingly greater ability to discriminate between signal and no signal). Hits and false alarm proportions of zero were replaced with $.5/N$, and proportions of 1 were replaced with $(N - .5)/N$ (where N is the number of signal and no-signal trials; Macmillan and Kaplan 1985). By convention, during data analysis we labelled the following categories as 'signal': 'natural speed' in the 'natural speed versus fast speed' condition; 'cooperative' in the 'cooperative versus competitive' condition; 'competitive' in the 'competitive versus fast speed' condition; and 'cooperative' in the 'cooperative versus natural speed' condition.

RTs, accuracy, d' values and c values were submitted to separate ANOVAs with intention (natural speed versus fast speed; cooperative versus competitive; competitive versus fast speed; cooperative versus natural speed) and display type (video versus point-light) as within-subjects factors.

Bonniferroni corrections were applied (alpha level .05). The levels of c and d' were calculated for each condition and one-sample t-tests were performed to ascertain the participants' ability to distinguish between signal and no signal.

Results

The repeated-measure ANOVA on RTs yielded a statistically significant effect of intention ($F_{(3,57)} = 94.21$, $P < .001$, $\eta_p^2 = .83$ see Fig. 2a). Post-hoc comparisons revealed that RTs for the 'cooperative versus natural-speed' condition were longer than those for the 'natural speed versus fast speed', the 'cooperative versus competitive' and the 'competitive versus fast speed' conditions ($Ps < .001$). Furthermore, RTs for the 'competitive versus fast speed' condition were longer than those for the 'natural speed versus fast speed' condition ($P = .026$). No effect of type of display was found.

The ANOVA on the proportion of correct responses yielded a statistically significant effect of intention ($F_{(3,57)} = 177.27$, $P < .001$, $\eta_p^2 = .90$) and display type ($F_{(1,19)} = 25.95$, $P < .001$, $\eta_p^2 = .58$; see Fig. 2b). Post-hoc comparisons indicated lower accuracy values for the 'competitive versus fast speed' and the 'cooperative versus natural speed' conditions compared to the 'natural speed versus fast speed' and the 'cooperative versus competitive' conditions ($Ps < .001$). Accuracy values were lower for the point-light displays than for the video displays ($P < .001$).

c parameter values ranged from $-.28$ to $.23$ ($M = -.04$, $SD = .25$) in the video condition and from $-.14$ to $.17$ ($M = .03$, $SD = .25$) in the point-light condition. The ANOVA on c revealed a main effect of intention ($F_{(3,57)} = 26.03$, $P < .001$, $\eta_p^2 = .58$). Post-hoc comparisons indicated that the c values were higher for the 'competitive versus fast speed' and the 'cooperative versus natural speed' conditions compared to the 'natural speed versus fast speed' and the 'cooperative versus competitive' conditions ($Ps < .001$), thus suggesting that participants adopted a more conservative criterion (i.e. reluctance to report signal) when asked to discriminate between intentions associated with similar profiles of movements (see Table 1). Accordingly, mean c values for the 'cooperative versus natural speed' and the 'competitive versus fast speed' conditions were significantly above zero (Ps ranging from .02 to < .001) for both the video and point-light displays (also when corrected for multiple comparisons using the False
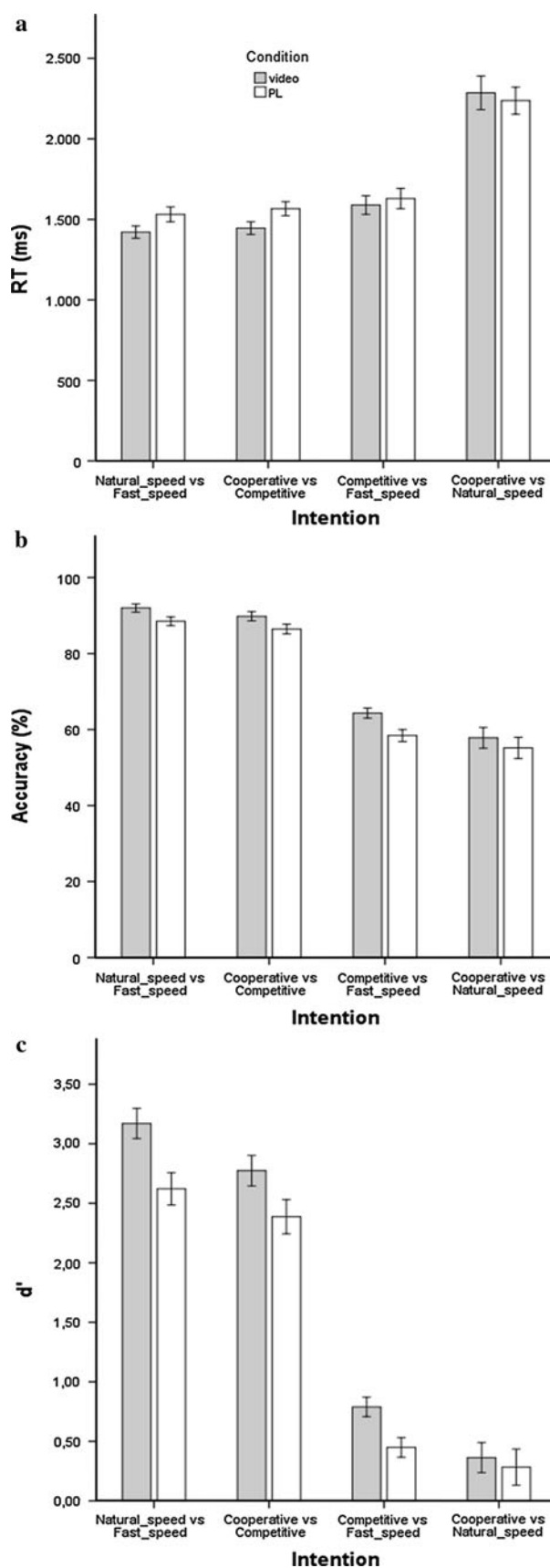
Discovery Rate method). For the 'natural speed versus fast speed' and the 'cooperative versus competitive' conditions, c values were significantly lower than zero for the video displays ($P < .01$), thus suggesting a bias towards reporting a signal ('natural speed' and 'cooperative', respectively). For the point-light displays, c values did not differ from zero ($P > .05$).

The ANOVA on d' yielded a significant main effect of intention ($F_{(3,57)} = 213.37$, $P < .001$, $\eta_p^2 = .93$) and display type ($F_{(1,19)} = 29.43$, $P < .001$, $\eta_p^2 = .61$; see Fig. 2c). Post-hoc comparisons indicated that the d' was lower for the 'competitive versus fast speed' and the 'cooperative versus natural speed' conditions compared to the 'natural speed versus fast speed' and the 'cooperative versus competitive' conditions ($Ps < .001$). Furthermore, d' values were lower for the point-light displays than for the video displays ($P < .001$; see Fig. 2b). Additional t-tests revealed that, for the video displays, d' values were lower for the 'competitive versus fast speed' and the 'cooperative versus natural-speed' conditions compared to the 'natural speed versus fast speed' and the 'cooperative versus competitive' conditions ($Ps < .001$). Moreover, d' values were lower for the 'cooperative versus natural speed' than for the 'competitive versus fast speed' condition ($P = .026$). This result was mainly due to the rate of false alarms, which was higher for the 'cooperative versus natural speed' than for the 'competitive versus fast speed' condition ($P = .03$). For the point-light displays, d' values were lower for the 'competitive versus fast speed' and the 'cooperative versus natural-speed' conditions compared to the 'natural speed versus fast speed' and the 'cooperative versus competitive' conditions ($Ps < .001$). No significant difference was found between the 'cooperative versus natural-speed' and 'competitive versus fast speed' conditions ($P = 1.000$). Mean d' values were significantly greater than zero (Ps ranging from .01 to < .001) for all the experimental conditions (also when corrected for multiple comparisons using the False Discovery Rate method), except for the 'cooperative versus natural speed' point-light condition ($t_{(19)} = 1.86$, $P = .079$).

Overall, these findings demonstrate that for both the video and point-light tasks, discrimination performance was most accurate for the 'natural speed versus fast speed' and 'cooperative versus competitive' conditions, less accurate for the 'competitive versus fast speed' condition, and least accurate for the 'cooperative versus natural speed' condition. For the point-light task, in particular, discrimination between cooperative and natural speed actions was at chance level. In line with results from the PCA (see "Methods" section), this suggests that the similarity of the kinematic profiles made it more difficult to discriminate between cooperative and individual natural-speed movements than between the other types of movements.

The relationship between accuracy of discrimination and kinematic properties for video and point-light displays

To investigate whether the same kinematic information predicted performance in the video and the point-light displays, we examined the relationship between accuracy of discrimination and the kinematic properties of the observed reach-to-grasp movements for the two types of displays. To do this, we first calculated the mean proportion of correct responses (accuracy) for each type of observed action (natural speed, fast speed, cooperative, competitive), in each trial. This was done separately for the video task and the point-light task. Then, we fitted four repeated measures GLMs, predicting accuracy scores (one for each type of observed action), with display-type (video vs. point-light) as a repeated measures factor and kinematic components (global component, grip timing component and wrist deceleration component) as covariates. If participants used the same kinematic information to discriminate between intentions in the two types of displays, we would expect no interaction between display type and the three kinematic components.

In line with this prediction, our results revealed no significant interaction effect for the global component and the grip timing component (Ps ranging from .130 to .858). A significant interaction effect was only found for the grip deceleration component in the competitive actions ($F_{(1,21)} = 7.87$, $P = .011$). To explore this result further, we examined the correlations between accuracy scores and wrist deceleration for the video and the point-light displays separately. A significant correlation between wrist deceleration and accuracy was found for the video display ($r_{(26)} = -.418$, $P = .037$), but not for the point-light display ($r_{(26)} = .003$, $P = .990$). This may suggest that for competitive actions, participants were able to exploit the information conveyed by the wrist deceleration component in the video task, but not in the point-light task.

Taken together, these results indicate that in discriminating between intentions from motion participants relied on almost the same kinematic information for the video and the point-light tasks.

Discussion

Observers are attuned to advance movement information and can use this information to predict others' actions. Here, we demonstrate how kinematic information from prehensile movements is sufficient to discriminate between movements performed with different social intentions.

Kinematic cues in discrimination between intentions

Social context shapes action planning in such a way that, although the object to be grasped remains the same, different kinematical patterns for individual actions and actions preparing for a subsequent social interaction are observed (Becchio et al. 2008a; b; Sartori et al. 2009; for a review see Becchio et al. 2010). Our results provide direct evidence that these differences, occurring at the early stage of action performance, might constitute significant cues for discriminating between intentions. By simply observing another person reaching towards an object and grasping it, participants were able to anticipate whether the object was grasped with the intent to cooperate, compete, or perform an individual action. Although predictions were more accurate for the video task, prediction performance was not disrupted for the point-light task, suggesting that essential kinematic information available in point-light displays was indeed sufficient for intention-from-motion judgement. These findings indicate that observers are able to infer social intention from visual kinematics of prehensile movements. Most importantly, they demonstrate that participants relied on the same landmarks to discriminate between social intentions under either full light or point-light conditions. This suggests that observers not only have the ability to use kinematic information when no other information is available, but actually use kinematic information to discriminate between intentions when watching the motion of others under full light conditions.

The role of kinematic information in intention-from-motion judgement has been shown in a number of previous point-light studies conducted in sports settings (Abernethy et al. 2001; Abernethy and Zawi 2007; Abernethy et al. 2008; Shim et al. 2005). Critically, the present study is the first to demonstrate that *social* intentions can be inferred from isolated prehensile movements under point-light conditions. This finding concurs with previous results by Sartori and colleagues (2011) who also suggest that other people's social intentions can be inferred from prehensile movements under full light conditions.

Cooperative intentions in video and point displays

For both types of displays, discrimination was most accurate for the 'natural speed versus fast speed' condition and for the 'cooperative versus competitive' condition; less accurate for the 'competitive versus fast speed' condition and for the 'cooperative versus natural speed' condition. Whereas these findings suggest that the pattern of advance information pick-up across conditions is similar for both types of displays, we observed an interesting discrepancy between the video and point-light tasks for discrimination between cooperative and natural-speed movements. For the

video task, prediction of accuracy was lower for the 'cooperative versus natural speed' than for the 'competitive versus fast speed' condition. In contrast, for the point-light task, no significant difference was observed between the 'cooperative versus natural speed' and 'competitive versus fast speed' condition. This result was mainly due to the high rate of false alarms, which was higher for the video task in the 'cooperative versus natural speed' condition compared to the 'competitive versus fast speed' condition ($P < .05$). A similar pattern of results was reported by Sartori and colleagues (2011) for judgements of intention in video displays under different temporal and spatial occlusion conditions. These authors interpreted such finding as evidence of a cooperative bias: People are naturally inclined to cooperate with others and, apparently, tend to see cooperation even when no cooperation exists.

In the present study, over-attribution of cooperative intention was evident in the video task, but not in the point-light task. This might signify that perceiving actions performed with a non-cooperative intent as cooperative is modulated by the type of display. Evidence that the appearance of the character used to render the motion influences action perception has been provided by adding anthropomorphic features to point-light characters (Chaminade et al. 2007). Whereas sensitivity was not affected by the rendering style, response bias towards perceiving a motion as biological decreased as a function of characters' anthropomorphism. Future studies using variations of animated characters' appearance may help to clarify whether anthropomorphism and stimulus complexity affect the tendency to perceive individual actions as cooperative.

A further issue is whether changing the instructions might affect accuracy. In the present study, participants were requested to respond as quickly and accurately as possible. This might have determined possible differences in speed-accuracy trade-off across conditions and participants. An interesting question to be addressed in future research is whether performance in point-light tasks would be improved in the absence of time constraints.

Intention—movement judgements: the role of motor simulation

The central advance of this study is the demonstration that observers are attuned to kinematic information from prehensile movements and use this information to distinguish reach-to-grasp movements performed with different social intents. Because, prehensile movements have different motion signatures depending on the actor's social intention, monitoring the kinematic properties of prehensile movements seems sufficient for observers to decide whether the object is grasped with the intent to cooperate with a partner, compete against an opponent or perform an individual action.

What kind of mechanisms do observers rely upon? It has been proposed that an important function of the motor system lies in the prediction of others' actions (Blakemore and Frith 2005; Prinz 2006; Wilson and 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, perceptual and motor systems share representations for actions (common-coding hypothesis; Prinz 1997) and 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 and Flanagan 2001).

Several studies point to a predictive function of the motor system in action observation. First, observing motor acts that are within the observer's motor repertoire activates some of the same motor regions activated during the execution of the same actions (e.g. Calvo-Merino et al. 2005; for a review see Rizzolatti and Sinigaglia 2010). The fact that this motor activation also occurs prior to a predicted movement suggests that the observer's motor system anticipates, rather than merely reacts to others' actions (Kilner et al. 2004; see also Umiltà et al. 2001). Second, observers who are expert in producing a given action are also more accurate in predicting the outcome of the same action performed by another person (Abernethy et al. 2001; Abernethy and Zawi 2007; Abernethy et al. 2008; Sebanz and Shiffrar 2009). For example, expert badminton players are better at anticipating the direction and depth of a stroke compared to non-experts (Abernethy and Zawi 2007; Abernethy et al. 2008). Similarly, basketball athletes are able to predict shot outcome (i.e. 'in' or 'out') more accurately and earlier than novices and visual experts, i.e. coaches and sport journalists, who are presumed to have no motor but comparable visual experience (Aglioti et al. 2008; see also, Wöllner and Cañal–Bruland 2010). Moreover, in accordance with a corollary hypothesis derived from the common coding theory, a high degree of overlap between perceptual and action representations facilitates action perception (Schütz-Bosbach and Prinz 2007). Observers demonstrate the greatest visual sensitivity to their own actions, with which they have the greatest motor experience (Knoblich and Flach 2001). This suggests that participants use their own motor experience to perceive and anticipate others' actions.

One possibility is thus that in the present study, participants relied on simulation processes occurring within their own motor system to anticipate the actor's social intention in grasping the object. Vingerhoets and colleagues (2010) recently demonstrated, that discriminating between an actor's intention to move or use an object based on the visual properties of the movement involves multifocal intraparietal activations, including the anterior, middle and caudal segments of the intraparietal sulcus. Because these parietal regions are strongly associated with motor behaviour, this finding supports the motor simulation hypothesis for intention-from-movement judgements. Future neuroimaging studies employing paradigms such as those used here might be needed to test whether the same mechanism of motor simulation extends to discrimination between social intentions.

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