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The case of Dr. Jekyll and Mr. Hyde: A kinematic study on social intention

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Abstract

The aim of the present study was to investigate the effects of social intentions on action. Participants ($N = 13$) were requested to reach towards, grasp an object, and either pass it to another person (social condition) or put it on a concave base (single-agent condition). Movements' kinematics was recorded using a three-dimensional motion analysis system. The results indicate that kinematics is sensitive to social intention. Movements performed for the 'social' condition were characterized by a kinematic pattern which differed from those obtained for the 'single-agent' condition. Results are discussed in terms of a motor simulation hypothesis, which assumes that the same mechanisms underlying motor intention are sensitive to social intentions.

Keywords: Social cognition; Social intentions; Social action; Kinematics; Reach-to-grasp

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1. Introduction

A current controversy concerns the role of the motor system in understanding social intentions (Beer & Ochsner, 2006; Jacob & Jeannerod, 2005). According to simulation theory, motor processes underlie the execution of actions as well as the understanding of other's people intended action (e.g. Decety & Grèzes, 2006; Gallese, 2001, 2003; Gallese & Goldman, 1998; Jackson & Decety, 2004). Each time an individual sees an action performed by another individual, motor simulation transforms audio–visual information about a physical movement into knowledge about an intentional action. This implicit knowledge is what allows us to penetrate the *motor intention* of another individual's action, i.e. to understand what she is doing.

A controversial issue is whether the same mechanism of motor simulation may account for our understanding of *social intentions*, i.e. intentions directed at other persons. Suppose an observer is watching another

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person's intentional action. Motor simulation allows the observer to represent the model's motor intention (e.g. grasping an apple). The question is: will motor simulation also allow him to distinguish whether the observed action is executed with a social goal (e.g. offering the apple) or with a purely individual goal (e.g. eating the apple)?

A reason of scepticism is that, differently from motor intentions, social intentions do not stand to actions in a one–one relation. Jacob and Jeannerod (2005), capitalizing on the so-called 'mirror' cells,[1] propose the following thought-experiment.

> Consider Dr. Jekyll and Mr. Hyde. The former is a renowned surgeon who performs appendectomies on his anesthetised patients. The latter is a dangerous sadist who performs exactly the same hand movements on his non anesthetised victims. As it turns out, Mr. Hyde is Dr. Jekyll. Suppose that Dr. Watson witnesses both Dr. Jekyll's and Mr. Hyde's actions. Upon perceiving Dr. Jekyll, alias Mr. Hyde, execute the same motor sequence twice, whereby he grasps his scalpel and applies it to the same bodily part of two different persons, presumably the very same mirror neurons produce the same discharge in Dr. Watson's brain. Dr. Jekyll's motor intention is the same as Mr. Hyde's. However, Dr. Jekyll's social intention clearly differs from Mr. Hyde's: whereas Dr. Jekyll intends to improve his patient's medical condition, Mr. Hyde intends to derive pleasure from his victim's agony.

Simulating the agent's movements (through the mirror system) might allow an observer to represent the agent's motor intention, but will not allow him to represent the agent's social intention (Jacob & Jeannerod, 2005). A simply motor equivalence between observed action and its motor representation in the observer's brain, can tell us "what" the action is (e.g. that's a grasping), but not "why", i.e. the social intention entertained by the agent.

This conclusion relies on the premises that Mr. Hyde's movements are the same as Dr. Jekill. Social intentions, is claimed, stand to actions in a many–one relation: the very same action can be at the service of different social intentions (Jacob, 2006). The question addressed by the present study concerns the plausibility of this *many–one assumption*. Is it possible that different social intentions correspond to exactly the same external movements? Is it possible that the same bodily movements are in one occasion a set of individual acts, and, on another occasion, constitute a social action?

A partial answer may come from kinematical studies. For example, it has been demonstrated that intention mechanisms modulate motor activation (Castiello, 2003; Castiello, Lusher, Mari, Edwards, & Humphreys, 2002; Edwards, Humphreys, & Castiello, 2003). In addition, Georgiou, Becchio, Glover, and Castello (2007) revealed kinematic patterns for cooperative and competitive behaviour, which were distinct from those obtained by the same participants for movements having similar requirements in terms of speed and accuracy, but performed in isolation. In this study, two participants acted together coordinating their actions in space and time, therefore a direct influence of the action of the partner might explain the social effect on kinematics.

In the present study, we ask whether kinematics is sensitive to the social intention to affect the behaviour of another person. Specifically, we asked participants to produce intentional actions in two different contexts provided by either an individual or a social task. For the individual task, participants were requested to act in isolation (single-agent condition). They were requested to reach towards and grasp an object and to move it from one spatial location to another. For the social task participants were requested to reach towards and grasp the same object as for the 'individual' task, but to pass it to a partner (social condition). Moving an object and passing an object are both intentional action; both involve a movement of translation, from one spatial location to another spatial location. The critical difference is in the intentional component: whereas moving an object realizes a purely individual intention, passing an object necessarily involves a social intention, i.e. the intention to affect a conspecific's behaviour as part of one's reason to act. This is what happened in the social condition, in which participants passed the object to a partner, who received the object and then re-positioned it on the initial target position. What we were interested in was the effect of social intention on kinematics.

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[1] Discovered within the ventral premotor cortex of the monkey brain, these neurons discharge both when the agent performs an action and during the observation of a similar action (Di Pellegrino, Fadiga, Fogassi, Gallese, & Rizzolatti, 1992; Gallese, Fadiga, Fogassi, & Rizzolatti, 1996; Rizzolatti, Fadiga, Gallese, & Fogassi, 1996). This interpersonal mirroring has been proposed as the fundamental mechanisms of motor simulation (Jacob, 2006).

Note that, whereas in the Georgiou et al. (2007) study two participants acted simultaneously, here the partner's action followed the participant's action. This should rule out the possibility that differences in kinematics may simply depend on the concomitant observation of another agent's action.

Finally, as to exclude that possible differences may be simply due to the presence of another person, we included a 'passive-observer' condition. This condition was similar to the 'single-agent' condition in that the participants' action (and intention) was not directed towards another person. The only difference was in the presence of passive observer who witnessed the action.

The results indicate a specific kinematic pattern for social intention, which differed from that obtained for the 'single-agent' and the 'passive-observer' condition.

2. Methods

2.1. Participants

Thirteen students (11 women and 2 men, ages 20–31 years) took part in the experiment. All participants were right handed, had normal vision and were naïve with respect to the purpose of the experiment. Participants gave their written consensus prior to the experiment.

2.2. Stimulus

The stimulus was an egg-shape (long axis = 5.7 cm) object positioned on a black table in front of the participant at a distance of 21 cm from the hand starting position along the midsagittal plane (see Fig. 1a).

2.3. Apparatus

Reflective passive markers (diameter = 0.25 cm) were attached to (a) the wrist, (b) the index finger, and (c) the thumb of right hand. The wrist marker was used to measure the *reaching component* of the action, whereas the finger and the thumb markers were used to measure the *grasp component* of the action. Movements were recorded using an ELITE motion analysis system (Bioengineering Technology & Systems [B|T|S]). Four infrared cameras (sampling rate 100 Hz) placed 120 cm away from each of the four corners of the table (see Fig. 1a) captured the movement of the markers in 3D space. Co-ordinates of the markers were reconstructed with an accuracy of 0.2 mm over the field of view. The standard deviation of the reconstruction error was 0.2 mm for the vertical (Y) axis and 0.3 mm for the two horizontal (X and Z) axes.

2.4. Procedure

Participants were tested individually in a dimly lit room. Before each trial, the right hand of each participant rested on a starting pad (brown velvet cloth 7×6 cm) with the index finger and the thumb gently opposed. The starting pad was attached 3 cm away from the edge of the table in a midsagittal position 15 cm away from the midsection (Fig. 1a). Participants were requested to start the action after a tone (880 Hz/200 ms) was presented. There were three experimental conditions:

1. *Single agent.* Each participant was requested to reach towards, grasp the stimulus, and put it in a concave base (12-cm diameter) positioned on an end-pad located at his/her right side at a 28-cm distance from the target location (see Fig. 1a). After each trial, the participant re-positioned the stimulus on the initial target location. Note that the base was given a concave shape matching the hand shape adopted by the experimenter during the 'social' condition (see below). Further, also the size and the location of the base matched the size and the location of the experimenter's hand.
2. *Social.* Each participant was requested to reach towards, grasp the stimulus, and pass it to a partner (see Fig. 1b). The partner was seated to the far right side of the table with the hand supine resting on the end-pad. The partner received the object and then re-positioned it on the initial target location.

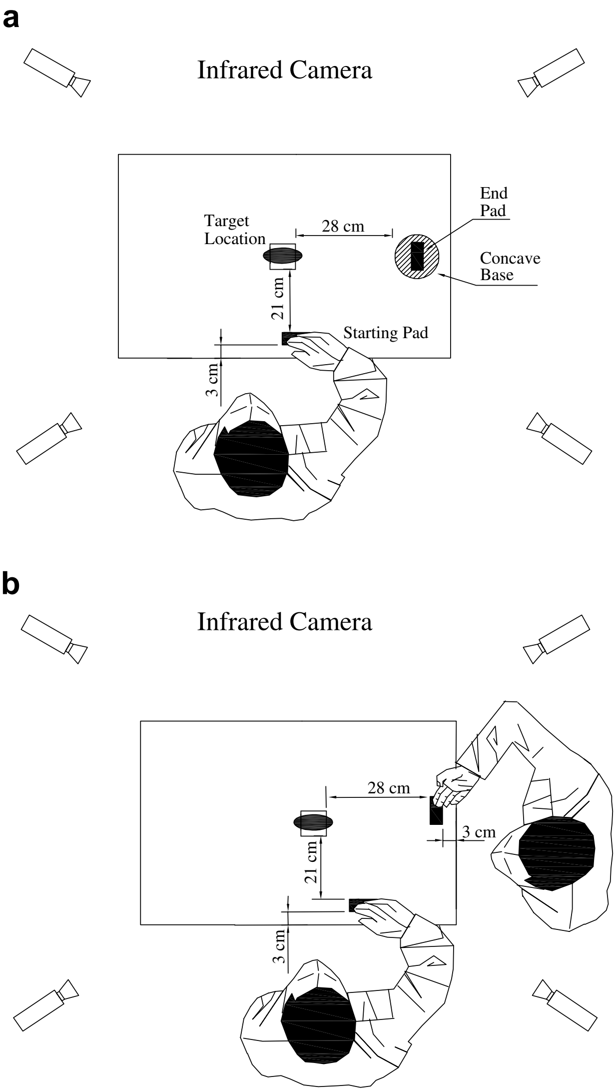

Fig. 1. Graphical representation of the experimental set up for the single-agent condition (a) and the social condition (b). The concave base is transparent as to show that it was located on top of the end-pad (a).

3. *Passive-observer.* Each participant performed the same action as for the “single-agent” condition, but in the presence of a passive observer seated at the far right side of the table simply observing the scene. After each trial, the participant re-positioned the stimulus on the initial target location.

The order of conditions was randomized between participants. Each subject performed 10 trials for each condition.

2.5. Data processing

The ELIGRASP software package (B|T|S|) was used to analyze the data and provide a 3D reconstruction of the marker positions as a function of time. The data were then filtered using a finite impulse response linear filter (transition band = 1 Hz, sharpening variable = 2, cut-off frequency = 10 Hz). Following this operation, the tangential speed of the marker on the wrist, and the distance between the index finger and the thumb were computed. These data were used to determine the onset and offset of the movement using a standard algorithm (threshold for movement onset and offset was ~5 cm/s). The onset was taken as the earliest time at which movement of the wrist occurred. The offset was taken at the latest time at which the movement of the thumb and index finger occurred.

2.6. Data analysis

The statistical analysis was confined to the dependent variables thought to be specifically relevant to the hypothesis under test. In particular, these variables (see below) have been chosen because, as previously demonstrated, they have been proved to be sensitive to variations in social context (Georgiou et al., 2007). Because the action was performed in two steps, reach towards and grasp the stimulus ('reach-to-grasp' phase) and place the stimulus either in the concave base or in the experimenter's hand ('place' phase) were analysed separately. The parameter concerned with the grasp component was obviously considered only for the reach-to-grasp phase. Conversely parameters concerned with the reaching component were analysed for both movement phases.

For the first 'reach-to-grasp' phase, the maximum distance between the two markers positioned on the index finger and the thumb (amplitude of maximum grip aperture), the amplitude of peak grip opening velocity (the time at which the fingers reached the maximum velocity during the opening phase), the time and amplitude of peak velocity of the arm and the wrist pathway were analyzed. For the second 'place' phase time and amplitude of peak velocity, wrist trajectory height and length of pathway were considered. Given that we expect the kinematic patterns for social vs. non-social action to differ with respect to movement speed, possible kinematic differences may be better understood when the occurrence of kinematic events are expressed in terms relative to the overall movement time. Following this assumption, each temporal value of the reach and grasp component was normalised as a percentage of movement time (relative values).

The means for each kinematic parameter of interest for the three experimental conditions were determined for each participant. For each dependent variable, the means for each participant were then entered into a one-way within-subjects analysis of variance (ANOVA). The within subjects factor was experimental condition (single-agent, passive-observer, social). Post hoc comparisons were carried out using *t*-test. Preliminary analyses were conducted to check for normality, sphericity (Mauchly test), linearity, univariate and multivariate outliers, homogeneity of variance–covariance matrices, and multicollinearity, with no serious violations noted.

3. Results

3.1. Reach-to-grasp phase

For this phase the main factor experimental condition was statistically significant for the amplitude of maximum grip aperture ($F(2,12) = 3.68$, $p < .05$) and the amplitude of peak grip opening velocity ($F(2,12) = 3.75$, $p < .05$). Post hoc contrasts revealed that maximum hand aperture and the amplitude of peak grip closing velocity were lower for the social than for the single agent condition (63 vs. 65 mm; 206 vs. 232 mm/s, respectively; ps < .05).

3.2. Place phase

The main factor experimental condition was significant for amplitude of wrist trajectory height ($F(2,12) = 24.13$, $p < .001$), length of wrist trajectory ($F(2,12) = 10.28$, $p < .05$), amplitude ($F(2,12) = 8.85$, $p < .001$) and time of peak velocity ($\mathrm{F}(2,12) = 4,28$, $p < .05$). Post hoc comparisons revealed that the wrist pathway was longer and the wrist trajectory height was higher for the 'social' than for the 'single-agent' condition ($p < .01$; see Fig. 2a and b). Furthermore, amplitude and time of peak velocity were lower and earlier for the 'social' than for the 'single-agent' condition ($p < .05$; see Fig. 2c and d). No significant differences were found when comparing the 'single-agent' and the 'passive-observer' conditions.

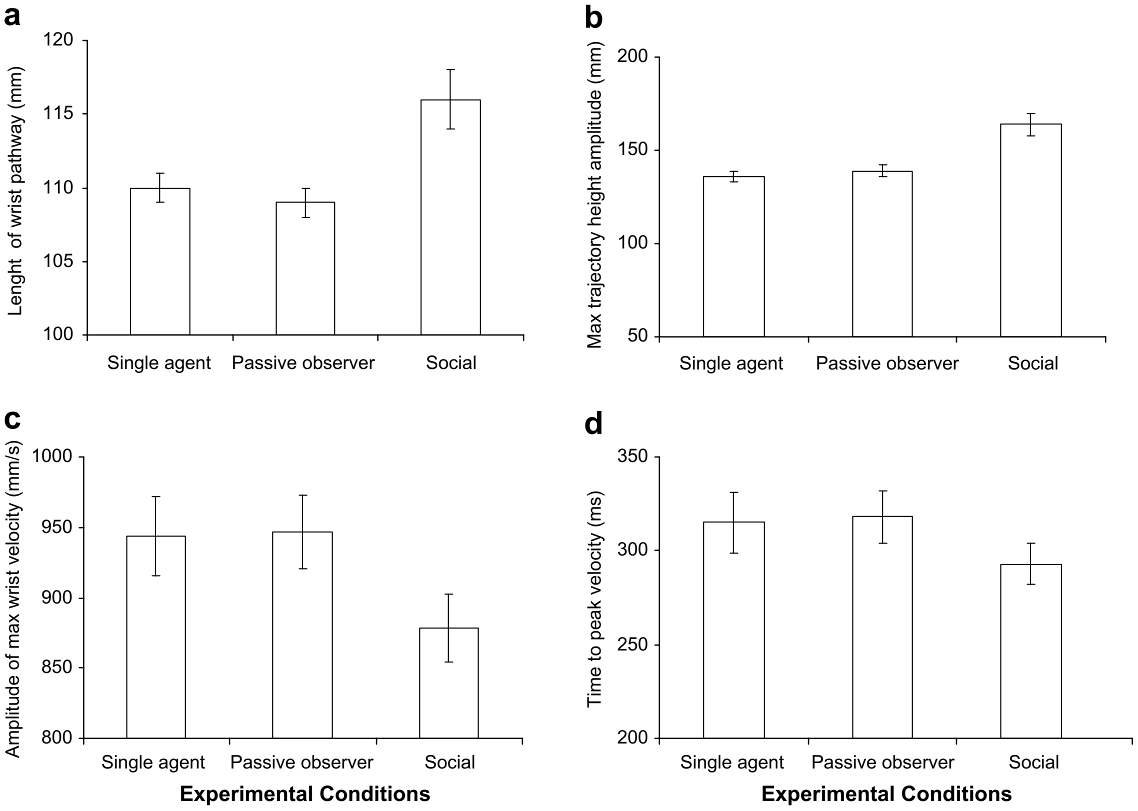

Fig. 2. A graphical representation of the differences between the ‘single-agent’, ‘social’ and ‘passive-observer’ conditions for the parameters wrist trajectory height (a), length of pathway (b), amplitude of peak velocity (c) and time to peak velocity (d). Bars represent the standard error.

4. Discussion

In this study, we investigated the effect of intention on the performance of the action of grasping an object and translating it from one spatial location to another location. This motor sequence could be executed with the intention to simply move the object (individual condition) or to pass it to a partner (social condition).

In line with our prediction, results revealed specific motor patterns for individual intended actions and actions motivated by a social intention. In particular, both the ‘reach-to-grasp’ and the ‘place’ phase were sensitive to the experimental manipulation. For the reach-to-grasp phase two key parameters, the amplitude of maximum grip aperture and the speed at which the hands open were found to be different for the ‘social’ condition. For instance, a lower speed of fingers’ closure for the ‘social’ condition may signify that participants needed to compute a more careful approach when passing the object to another person. This would be necessary as to grasp the object in a manner which is appropriate for passing it to another person. In contrast, when the object had to be placed in the concave base (‘single-agent’ condition) the determination of the contact points for the fingers might not be so crucial. This is because the object could be placed in the concave base in whatever orientation without compromising the goal of the action. Therefore the speed of finger closure can be faster. In kinematic terms these results are in line with recent evidence showing a more careful modulation of hand shaping depending on the end-goal accuracy (Ansuini, Santello, Massaccesi, & Castiello, 2006).

As for the ‘reach-to-grasp’ phase the kinematics for the ‘place’ phase was different for the ‘social’ than for the ‘single-agent’ condition. Specifically, the results are suggestive of a more careful honing phase when the goal is nested within a social interaction. For example, a higher point of maximum trajectory height and an anticipated time to peak velocity are both indicative that a longer deceleration phase has been applied.

In other words, the action of passing an object into the hand of another person entails a more careful action than when the same object is placed within an inanimate container. This result is remindful of previous kinematic evidence suggesting that placing an object within a fragile container entails a longer deceleration phase than when placing the same object within a robust container (Marteniuk, MacKenzie, Jeannerod, Athenes, & Dugas, 1987).

The conventional view assumes that the difference between a social and an individual action lies exclusively in the mental component (e.g. Jacob & Jeannerod, 2005; but see also Searle, 1998). The present findings show how differences in intentions are reflected in the kinematics: specific kinematic patterns connote and distinguish an action executed with a social goal from an action motivated by an individual goal.

It might be said that these differences in kinematics are dictated by diverse end- goal accuracy constraints. We propose two possible reasons as to rule out such an alternative explanation. First, the shape, the size, and the location of the base for the single-agent condition matched the location, shape, and size of the experimenter's hand for the social condition. Second, and more importantly, despite no physical difference occurred in the reach-to-grasp phase across the two conditions, significant differences emerged. For instance, in line with what found for the place phase, the lower amplitude of peak grip opening is indicative of a more careful approach towards the object. These differences are suggestive of an influence of social intention on kinematics: the intention to affect the behaviour of another person shapes the kinematics of the action.

5. Implications for a motor theory of social cognition

The thought experiment involving Dr. Jekyll and Mr. Hyde should prove that motor processes do not play a role in recognizing social intentions. In contrast with this view, the present findings suggest that social intentions translate into specific motor pattern.

These results do not constitute direct evidence of an involvement of the motor system in recognizing social intentions. Yet, they provide evidence for the existence of differences in motor patterning depending on social context and intention. These differences, we surmise, may be used by the observer's motor system to discriminate between actions serving different intentions. If the very same action can serve different intentions (many–one assumption), then no information may be derived from actions in order to understand intentions. On the contrary, if intentions shape kinematics—as the present results show—mirroring an action may enable the observer to represent the agent's social intentions.

The above considerations are in line with the proposal that we directly perceive intentions in the actions of others (Gallagher, 2001; Gallese, 2006). In most of our every day interactions, we have a direct, immediate understanding of other persons' intentions because their intentions are explicitly expressed in their embodied actions. As a consequence, when observing another person's action, we do not only see a physical movement, but we "see" an intentional action. What the present results add to these notions is the specific role played by kinematics in translating social intentions into specific motor patterns. Kinematics operationalizes differences in intentions, so that the same motor sequence assumes different features depending on the intention (social vs. individual) motivating its execution.

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