Available online at www.sciencedirect.com
ScienceDirect
Cognition 106 (2008) 894–912
COGNITION
www.elsevier.com/locate/COGNIT

Both your intention and mine are reflected in the kinematics of my reach-to-grasp movement

Cristina Becchio [a], Luisa Sartori [b], Maria Bulgheroni [b], Umberto Castiello [b,c,*]

[a] *Centro di Scienza Cognitiva, Dipartimento di Psicologia, Università di Torino, Italy*
[b] *Dipartimento di Psicologia Generale, Università di Padova, 35131 Padova, Italy*
[c] *Department of Psychology, Royal Holloway, University of London, UK*

Received 27 August 2006; revised 9 May 2007; accepted 11 May 2007

Abstract

The aim of the present study is to ascertain whether in a social context the kinematic parameters are influenced by the stance of the participants. In particular, we consider two basic modes of social cognition, namely cooperation and competition. Naïve subjects were asked either to cooperate or to compete with a partner (a professional female actor), whose attitude could be either congruent or incongruent with the task instructions. Thus, on congruent conditions, subjects cooperated or competed with a partner showing a congruent cooperative or competitive attitude. On incongruent trials, the partner assumed an attitude that was manifestly in contrast with the instruction: competitive for the cooperative task, cooperative for the competitive task. We hypothesized that this mismatch between partner's attitude and instruction would produce a sort of unexpected social situation, affecting the kinematics of reach-to-grasp movement performed by the agents. If cooperative and competitive kinematic patterns are sensitive to the partner's attitude, then we should expect that an incongruent attitude have the potency to determine a reversal in kinematic patterning. Results revealed that for the incongruent trials the specific kinematic patterns for cooperation and competition found for the congruent conditions where modified according to the incongruent attitude

* Corresponding author. Fax: +39 049 8276600.
E-mail address: umberto.castiello@unipd.it (U. Castiello).

doi:10.1016/j.cognition.2007.05.004

assumed by the model actor. We suggest that this 'attitude' contagion is part of a sophisticated system that allows us to infer about the intention to act in a social context.

Keywords: Competition; Cooperation; Kinematics; Reach-to-grasp; Social cognition; Social intention

1. Introduction

It is a common place to say that human beings are social and disposed to cooperate. "Kin-altruism" and "reciprocal altruism" ground cooperative behaviours in animals. Analogously, we think that people are disposed to behave cooperatively at least with respect to their kin and, by extension, with all human beings. Whereas a generalized, biologically based disposition to cooperate seems to exist in humans (Trivers, 1971, 1985), it is rather difficult to determine under what conditions people actually cooperate rather than defect, act competitively, selfishly, or even aggressively (Tuomela, 2000).

From an economic perspective, the question is framed as a choice made by an individual between two behavioural responses, cooperating or non-cooperating, determined by differences in tangible outcomes such as food or money. Following a utility maximization principle, individuals are supposed to choose the strategy that yields a preferable outcome.

When cooperating and non-coperating occur in the real word, however, they are often not only associated with different outcomes but also with different behaviours. Consequently, the choice between cooperating or non-cooperating will not only be determined by tangible outcomes, but also by social dimensions of cooperative behaviours such as the partners' attitude, the level of coordination and the relationship among cooperators (e.g., age, sex, past encounters).

Laboratory experiments tend to minimize the impact of such factors by eliminating the exposure to social dimensions. Using what Colman (2003) characterized as the "bedrock of methodological individualism", anonymous individuals are asked to express their preferences while physically isolated in separate compartments that eliminate – in part or totally – social interaction. This approach has been used in behavioural experiments with both animals and humans (Shuster & Perelberg, 2004). Recent neuroimaging experiments on cooperation and competition adopt the 'isolation paradigm' approach testing single participants while playing a game with a real or fictitious partner outside the scanner (Decety, Jackson, Sommerville, Chaminade, & Meltzoff, 2004; Gallagher, Jack, Roepstorff, & Frith, 2002; McCabe, Houser, Ryan, Smith, & Trouard, 2001; Rilling et al., 2002). In this respect, these 'isolation' experiments reflect the underlying assumption that a choice between cooperation and non-cooperation is really the same as a choice between two individual acts associated with different outcomes.

In this study, we adopt a rather different perspective. Specifically, we consider how the kinematics of an action performed in the context of a social interaction are sensitive to the cooperative or competitive stance of the participants.

In a previous study, we have already demonstrated the existence of motor patterns, which reflect the agent's intention to act in a social context (Georgiou, Becchio, Glover, & Castello, 2006). We found different kinematical patterns for single independent actions and actions preparing to a subsequent social interaction. The experiment analyzed the kinematics of the very same action – reach and grasp for a wooden block – in two different contexts provided by a cooperative and a competitive task. For the cooperation task, participants assigned in pairs were required to reach and grasp for their respective object and to cooperate as to form a tower by putting one object on the top of the other in the middle of the working surface. The competition task was similar to the cooperation task except that participants had to compete as to put their object in the middle of the working surface first. In contrast to isolation models predicting no differences between actions having the same goal, results revealed how the planning and execution of an action are modulated with respect to the intention of the agent. The adoption of a particular intention (individual vs social, cooperative vs competitive) translates into a measurable kinematic pattern, which even in the reach-to-grasp phase (reach-to-grasp for an object) is different from the kinematic pattern of the same action motivated by a different intention. Prior to the interaction, the agent's intention to act cooperatively vs competitively shapes the kinematics of the action.

The study by Georgiou et al. (2006) focused on the *agent*'s prior intention (Searle, 1983), i.e., on the intention orienting the action of the agent as a whole, whereas in the present study we focus on the intentional stance taken towards the *partner*. Social behaviours rest on the fundamental capacity to understand the actions of other social agents in terms of their mental states – what Dennet (1996) described as "taking an intentional stance". Suppose an agent is asked to cooperate with a partner clearly displaying the intention to compete. Is the kinematics of the action influenced by the intention to compete that the agent attributes to the partner? The same question arises with respect to an agent who is asked to compete with a partner displaying the intention to cooperate.

The aim of the present study was to explore this question by manipulating the attitude of the partner during the reach-to-grasp phase of a social interaction. Subjects were requested to reach for their respective objects (reach-to-grasp phase). Once they had grasped the objects, they had either to cooperate or to compete with a partner (interaction phase). The partner was a semi-professional stage actor that was instructed as to assume an attitude either congruent or incongruent with the task instructions. For the congruent trials, the actor assumed an attitude congruent with the task instructions: cooperative for the cooperative task, competitive for the competitive task. For the incongruent trials, the partner assumed an attitude that was manifestly in contrast with the instruction: competitive for the cooperative task, cooperative for the competitive task. We hypothesized that the mismatch between partner's attitude and instruction would produce a sort of unexpected social situation, affecting the kinematics of reach-to-grasp movement performed by the agents. If the task is to cooperate, but the partner assumes a competitive attitude, thus manifesting the intention to compete, then competitive features should emerge in the agent's kinematics. Conversely, if the task is to compete, but the partner assumes a cooperative attitude, manifesting the intention to cooperate, then the kinematic pattern of the agent should resemble that obtained for cooperation.

2. Methods

2.1. Subjects

Twelve subjects (6 females–6 males, ages 19–35) took part in the experiment. All subjects were right-handed, reported normal or corrected-to-normal vision and were naive as to the purpose of the experiment.

2.2. Actor model

A professional female actor (34 years of age) took part in the experiment and acted as a partner in conditions 5–12 as outlined below.

2.3. Stimuli

The stimuli were a pair of blue wooden blocks ($4 \times 4 \times 8$ cm). The stimuli were placed in the middle of the working surface at a distance of 18 cm away between them and 21 cm away from the hand starting position (Fig. 1a). A vertical line was drawn in the centre of the table, to guide each participant when moving their respective object to the middle of the table (Fig. 1a).

2.4. Procedures

The experiment was conducted under normal lighting conditions. The working surface was a 122×60 cm table. Before each trial, the right hand of each participant rested on a starting pad (blue velvet cloth 6×4 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). The subjects were requested to start the action after a tone (880 Hz/200 ms) was presented. For cooperation and competition tasks, two participants (a naïve subject and a professional actor) were seated opposite to each other. Naïve subjects believed that the actor was just another participant. They were required to reach and grasp for their respective objects (Fig. 1b) and to either cooperate so as to form a tower by putting one object on top of the other (Fig. 1c), or compete to be the first to place their object on the bottom (Fig. 1d).

Subjects were tested in 12 experimental conditions.

1. *Single-agent: Natural speed bottom.* In this condition, each subject was required to reach and grasp at a natural speed the stimulus positioned in front of his/her right hand and bring it in the middle of the working surface.

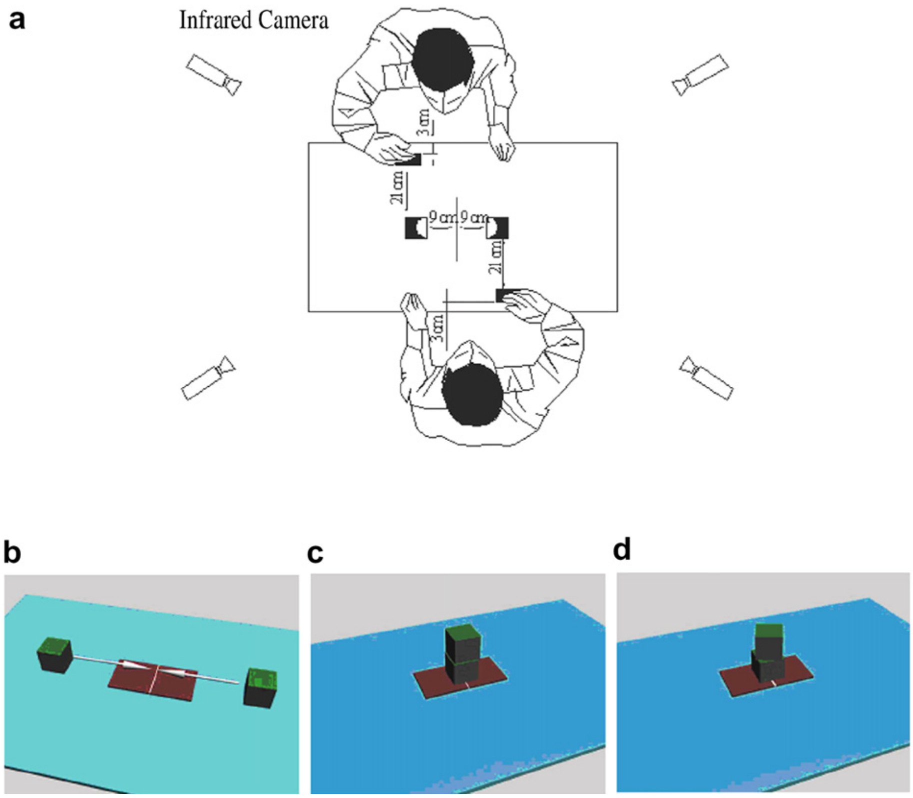

Fig. 1. Experimental set up. (a) Represents the subjects' posture, the positioning of the stimuli and the positioning of the infrared cameras. (b) Represents the direction of movement. (c and d) Represent the cooperation task and competition task, respectively. Note that for the 'cooperation bottom' task the object is brought in the middle of the table, whereas in the 'cooperation top' task the object is brought on top of another object in the middle of the table. Conversely, in the competition task participants compete to put their object in the bottom of the tower first (middle of the table).

2. *Single-agent: Natural speed top*. In this condition, each subject was required to reach and grasp at a natural speed the stimulus positioned in front of his/her right hand and put it on top of an object previously placed in the middle of the working surface.
3. *Single-agent: Fast speed bottom*. In this condition, each subject was required to reach and grasp as fast as possible the stimulus positioned in front of his/her right hand and bring it fast in the middle of the working surface.
4. *Single-agent: Fast speed top*. In this condition, each subject was required to reach and grasp as fast as possible the stimulus positioned in front of his/her right hand and put it fast on top of an object previously placed in the middle of the working surface.

5. *Passive observer: Natural speed bottom*. This condition was similar to the natural speed bottom—single agent condition except that each subject performed the action in the presence of another person (one of the experimenters observing the scene).
6. *Passive observer: Natural speed top*. This condition was similar to the natural speed top – single agent condition except that each subject performed the action in the presence of another person observing the scene.
7. *Passive observer: Fast speed bottom*. This condition was similar to the fast speed bottom – single agent condition except that each subject performed the action in the presence of another person observing the scene.
8. *Passive observer: Fast speed top*. This condition was similar to the fast speed top – single agent condition except that each subject performed the action in the presence of another person observing the scene.
9. *Congruent cooperation bottom/top condition*. The two participants (a naïve subject and the actor) seated opposite to each other and were required to reach for their respective objects. One participant was instructed to put it on the bottom whereas the other subject was instructed to put it on the top so as to form a tower (Fig. 1c). The top/bottom order was counterbalanced across subjects. In this condition, the actor assumed an attitude in line with the 'cooperation' instructions.
10. *Incongruent cooperation bottom/top condition*. The two participants seated opposite to each other and were required to reach for their respective objects (reach-to-grasp phase). One subject was instructed to put it on the bottom whereas the other subject was instructed to put it on the top to form a tower (interaction phase; Fig. 1c). The top/bottom order was counterbalanced across subjects. In this condition, the actor was covertly signalled by the experimenter to assume a 'competitive' attitude (facial expression and body posture) during the reach-to-grasp phase. To signal the actor as to assume an incongruent attitude, the experimenter pretended to adjust the stimuli on the working surface and touched the actor slightly on the back. This operation (without the back touch) was performed various times for both the congruent and incongruent conditions and from both the naïve and the actor model's side as to avoid that the naïve participant would associate this operation with the incongruent attitude. During the interaction phase, the actor cooperated with the partner as requested by the instructions.
11. *Congruent competition condition*. This condition was similar to the cooperation condition except that the subjects had to compete as to put first the respective object in the bottom of the tower (Fig. 1d). In this condition, the actor assumed an attitude in line with the 'cooperation' instructions.
12. *Incongruent competition condition*. This condition was similar to the cooperation condition except that the subjects had to compete as to put first the respective object in the bottom of the tower (Fig. 1d). In this condition, the actor was covertly signalled (as reported above) by the experimenter to assume a 'cooperative' attitude during the reach-to-grasp phase. During the interaction phase, the actor competed as requested by the instructions.

Participants performed 10 trials for experimental conditions 1–8 in separate blocks. For both the cooperation and competition conditions, the congruent and the incongruent trials were intermingled within a 100 trials block. In particular, the incongruent trials occurred only 20% of the total number of trials as to avoid predictive effects. This brought to 80 congruent trials (40 for cooperation and 40 for competition) and 20 incongruent trials (10 for cooperation and 10 for competition). Because of the different number of trials between congruent and incongruent trials, we randomly chose for subsequent analyses 20 congruent trials (10 for cooperation and 10 for competition) out of the 80 congruent acquired trials.

2.5. Recording techniques

The ELITE motion analysis system (Bioengineering Technology & Systems [BTS]) was used to record movements. Reflective passive markers (0.4 cm diameter) were attached on the (a) wrist: radial aspect of the distal styloid process of the radius; (b) index finger: radial side of the nail; (c) thumb: ulnar side of the nail. The wrist marker was used to measure the reaching component of the action. The finger and thumb markers were used to measure the grasp component of the action. When two subjects were acting simultaneously (cooperation and competition conditions) kinematics were computed for both subjects. 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. Coordinates 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.

2.6. Data processing

An in-house software package was used to analyse the data. The dependent measures specifically relevant to test the experimental hypothesis were those that, as identified in our previous study (Georgiou et al., 2006), were sensitive to differences in social attitude (cooperation and competition). They were (a) movement time; (b) amplitude of wrist peak velocity; (c) time of maximum grip aperture; and (d) amplitude of maximum grip aperture. Further, for the spatial trajectories the amplitude of the maximum height of the wrist trajectory from the working surface was considered.

2.7. Data analysis

Although the subjects' movement was performed in two steps, reaching and grasping the object and bringing the grasped object to a specific place, kinematics analyses were restricted to the phase leading up to the grasping of the object. This is because this phase was common to all experimental conditions. In the single agent condition, this movement preceded the individual action of placing the object on the table, whereas in the cooperative and the competitive task it was preparatory to the successive social interaction (interaction phase), being not part of the interaction itself.

We performed a series of one-way preliminary analyses of variance (ANOVA) on the measures of interest as to confirm the results obtained in our previous experiment (Georgiou et al., 2006). These analyses were carried on both the naïve group of participants and the actor model. The reason for carrying out such analyses was twofold. First, if the results of the preliminary analyses would confirm those obtained in our previous study, then we could concentrate our analyses on the four condition of interest for the present study (Conditions 9–12). Second, for the sake of brevity, we would avoid reporting already known data that are tangential to the scope of the present work.

These preliminary analyses checked for: (a) top/bottom differences for each kinematic parameter for each condition; (b) differences between natural slow movements performed alone and natural slow movements performed in the presence of a passive observer; (c) differences between fast movements performed alone and fast movements performed in the presence of a passive observer; (d) differences between natural slow movements performed in the presence of another person and the cooperative movements (which were performed quite naturally and slower); (e) differences between fast movements performed in the presence of another person and the competition movements (which were performed fast); (f) differences between the cooperative and the competitive movements.

In line with our previous findings (Georgiou et al., 2006), we found that for the dependent measures of interest there were no top/bottom differences, no differences between 'slow' and 'fast' movements performed alone or in the presence of a passive observer and large differences between cooperation and competition (see Table 1). Importantly there were differences within key kinematic landmarks (the chosen dependent measures) between the cooperative movements and the 'slow' movements performed alone or in the presence of a passive observer and between the competitive movements and the 'fast' movements performed alone in the presence of a passive observer (see Table 1). This signifies that, as we have already demonstrated, cooperative and competitive actions have clear and distinct kinematic patterning. For instance, movement duration was shorter and amplitude of peak velocity was higher for 'competitive' than for 'fast' movements performed alone. Conversely, movement duration was slower and the amplitude of peak velocity was lower for 'cooperative' than for 'slow' movements performed alone. These findings applied to both the actor model and the naïve group of participants. Consequently, top/bottom data were collapsed as well as those for natural and fast movements performed in the presence or absence of a passive observer. Subsequently we run an ANOVA with type of task (cooperation, competition) and type of trial (congruent, incongruent) as within-subject factors as to specifically test the hypothesis that independently from the overarching goal of the task (cooperate or compete) the incongruent social attitude assumed by the actor may bias the action of the naïve agent cooperating or competing with her. The same analysis was performed for the actor model kinematics. A p-value of 0.05 was considered significant after Bonferroni correction for multiple comparisons.

Correlation analyses were conducted to explore whether there was a linear relationship within the movements of the actor model and the naïve subjects for the con-

Table 1
Statistical results for the preliminary analyses performed on the contrasts and the dependent measure of interest for the naïve group of participants

Contrasts	Movement duration	Amplitude wrist velocity	Trajectory height	Deceleration time	Time of maximum grip aperture	Amplitude of maximum grip aperture
Top vs bottom	$F(1,11) = 1.04$, $p > 0.05$	$F(1,11) = 0.65$, $p > 0.05$	$F(1,11) = 2.12$, $p > 0.05$	$F(1,11) = 0.54$, $p > 0.05$	$F(1,11) = 1.18$, $p > 0.05$	$F(1,11) = 2.05$, $p > 0.05$
Slow alone vs slow (passive agent)	$F(1,11) = 2$, $p > 0.05$	$F(1,11) = 2.22$, $p > 0.05$	$F(1,11) = 0.52$, $p > 0.05$	$F(1,11) = 1.33$, $p > 0.05$	$F(1,11) = 0.88$, $p > 0.05$	$F(1,11) = 0.45$, $p > 0.05$
Fast alone vs fast (passive agent)	$F(1,11) = 1.21$, $p > 0.05$	$F(1,11) = 1.54$, $p > 0.05$	$F(1,11) = 2.76$, $p > 0.05$	$F(1,11) = 2.67$, $p > 0.05$	$F(1,11) = 0.75$, $p > 0.05$	$F(1,11) = 1.67$, $p > 0.05$
Fast alone vs competition	$F(1,11) = 18.21$, $p < 0.001$	$F(1,11) = 10.06$, $p < 0.001$	$F(1,11) = 11.43$, $p < 0.001$	$F(1,11) = 25.76$, $p < 0.0001$	$F(1,11) = 8.32$, $p < 0.01$	$F(1,11) = 7.06$, $p < 0.05$
Slow alone vs cooperation	$F(1,11) = 13.07$, $p < 0.001$	$F(1,11) = 17.46$, $p < 0.001$	$F(1,11) = 29.21$, $p < 0.0001$	$F(1,11) = 12.06$, $p < 0.001$	$F(1,11) = 20.13$, $p < 0.0001$	$F(1,11) = 11.43$, $p < 0.001$
Cooperation vs slow (passive agent)	$F(1,11) = 16.06$, $p < 0.001$	$F(1,11) = 7.32$, $p < 0.05$	$F(1,11) = 10.05$, $p < 0.001$	$F(1,11) = 34.76$, $p < 0.0001$	$F(1,11) = 12.83$, $p < 0.001$	$F(1,11) = 8.09$, $p < 0.05$
Competition vs fast (passive agent)	$F(1,11) = 38.69$, $p < 0.0001$	$F(1,11) = 44.39$, $p < 0.0001$	$F(1,11) = 56.71$, $p < 0.0001$	$F(1,11) = 31.28$, $p < 0.0001$	$F(1,11) = 9.65$, $p < 0.001$	$F(1,11) = 6.04$, $p < 0.05$
Cooperation vs competition	$F(1,11) = 70.43$, $p < 0.0001$	$F(1,11) = 48.56$, $p < 0.0001$	$F(1,11) = 10.14$, $p < 0.001$	$F(1,11) = 37.21$, $p < 0.0001$	$F(1,11) = 27.30$, $p < 0.0001$	$F(1,11) = 42.10$, $p < 0.0001$

gruent and incongruent competitive and cooperative conditions. In particular, we investigated the existence of such relationship for three key kinematic parameters using Pearson product-movement correlation coefficient: time to peak velocity, maximum peak height trajectory and time of maximum grip aperture. These parameters were chosen because they might allow inferring the degree of cross talk between the two agents during the social action. In line with previous findings, we expected significant correlation for these parameters for the cooperative congruent condition, but no significant correlation for the competition congruent condition (Georgiou et al., 2006). Further, in line with the hypothesis that the experimental manipulation would affect the agent's kinematics, we expected no significant correlation for the incongruent cooperation conditions.

3. Results

As previously demonstrated the reach-to-grasp action performed during a cooperation task show a longer movement duration, a lower amplitude peak velocity, a higher maximum height of the wrist trajectory, a later time of maximum grip aperture and a smaller amplitude of grip aperture than a reach-to-grasp action performed during a competitive task (Georgiou et al., 2006). Furthermore, whereas significant correlations emerged when comparing key kinematic landmark during the cooperation task, no significant correlations for the same measures were evident for the competitive task (Georgiou et al., 2006). With this is mind, the following sections report the effect of the incongruent social attitude on these well-established patterns.

3.1. Actor model kinematics

The interaction type of task by type of trial was significant for movement duration [$F(1,9) = 224.8$, M.S.E. = 45225.625, $p < 0.0001$], wrist peak velocity [$F(1,9) = 79.760$, M.S.E. = 22705.225, $p < 0.0001$], amplitude of the maximum height of the wrist trajectory from the working surface [$F(1,9) = 96.044$, M.S.E. = 632.025, $p < 0.0001$], time to maximum grip aperture [$F(1,9) = 145.606$, M.S.E. = 600.625,$p < 0.0001$] and the amplitude of maximum grip aperture [$F(1,9) = 191.510$, M.S.E. = 511.225, $p < 0.0001$. Post-hoc contrasts (ps < 0.05) revealed that, for the competition tasks, movement duration was longer for the incongruent than for the congruent condition (677 vs 621 ms). For the reaching component, the amplitude of wrist peak velocity was lower (676 vs 714 mm/s) and the height of the trajectory wrist was higher (70 vs 64 mm) for the incongruent than for the congruent condition. For the grasping component, the time of maximum grip aperture was later (56% vs 47%) and the amplitude of maximum grip aperture was smaller (84 vs 92 mm) for the incongruent than for the congruent condition.

The same influence of the assumed social attitude on movement kinematics was evident when comparing the action performed by the actor model in the congruent and incongruent cooperative condition. For example, movement duration was shorter (657 vs 737 ms) wrist peak velocity was higher (714 vs 675 mm/s) and the amplitude

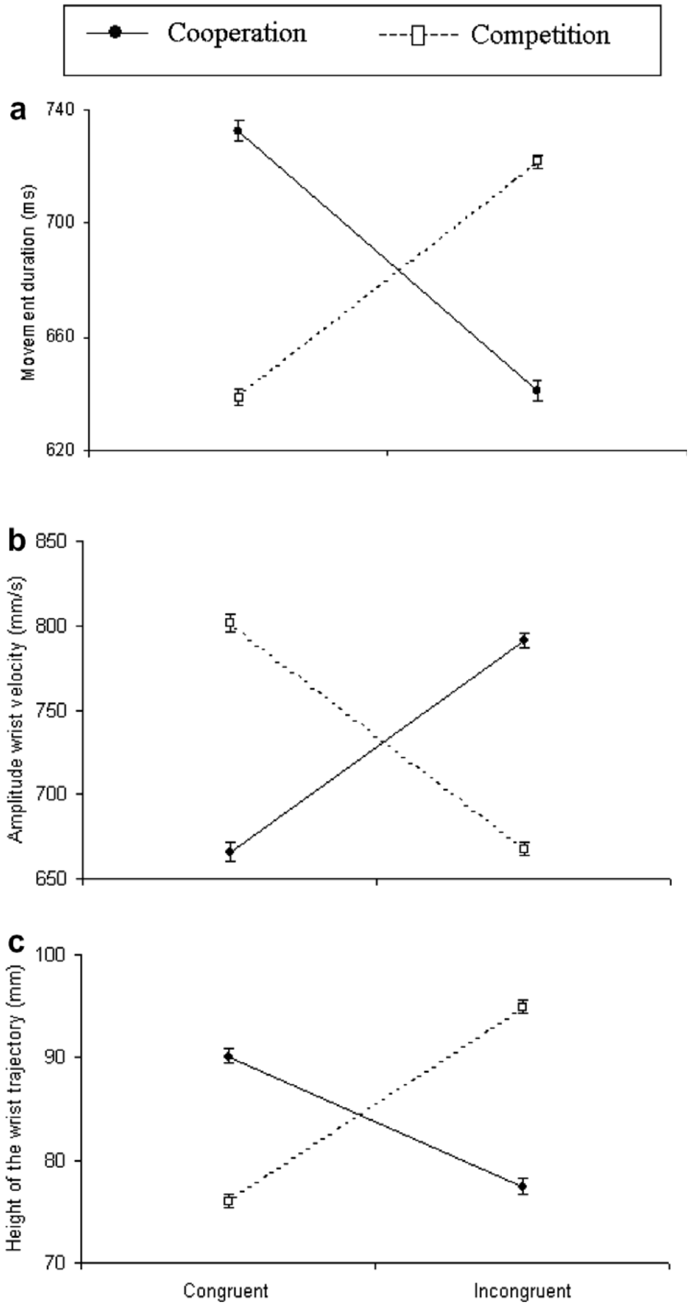

Fig. 2. Graphical representation for the interaction type of task by type of trial for movement duration (a), amplitude wrist velocity (b) and height of the wrist trajectory (c). Bars represent the standard error.

of the maximum height of the wrist trajectory from the working surface was lower (64 vs 70 mm) for the incongruent than for the congruent condition. For the grasping component, time and amplitude of maximum grip aperture were earlier (47% vs 55%) and wider (91 vs 84 mm) for the incongruent than for the congruent condition.

These results suggest that although the actor model was instructed to maintain the action pattern congruent with the task (competition or cooperation), kinematic features for the incongruent task emerged. This signifies that, independently from the instruction, assuming a certain attitude brought to a pattern of movement related to the assumed social attitude.

3.2. Naïve agent kinematics

The interaction type of task by type of trials was significant for movement duration [$F(1,119) = 624.061$, M.S.E. = 922867,102, $p < 0.0001$], the amplitude of wrist

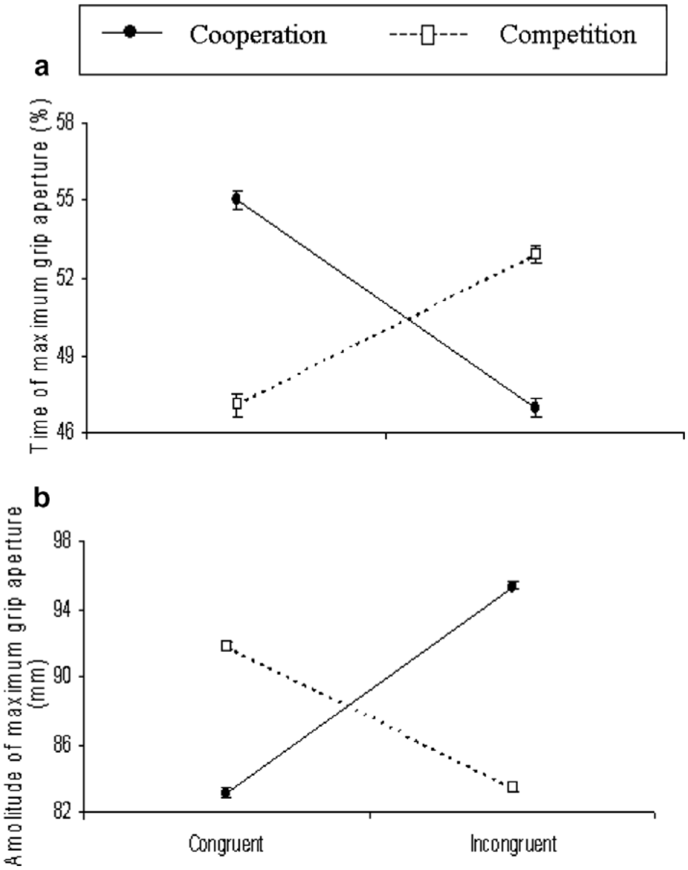

Fig. 3. Graphical representation for the interaction type of task by type of trial for time of maximum grip aperture (a) and amplitude of maximum grip aperture (b). Bars represent the standard error.

peak velocity [$F(1,119) = 654.109$, M.S.E. = 2015150,41, $p < 0.0001$], the amplitude of the maximum height of the wrist trajectory from the working surface [$F(1,119) = 439.455$, M.S.E. = 3004.219, $p < 0.0001$], the time of maximum grip aperture [$F(1,119) = 412.004$, M.S.E. = 5720.102, $p < 0.0001$] and the amplitude of maximum grip aperture [$F(1,119) = 1779.669$, M.S.E. = 12658.802, $p < 0.0001$]. Post-hoc contrasts (ps < 0.05) revealed that, for the competition tasks, movement duration was longer for the incongruent than for the congruent condition (see Fig. 2a). For the reaching component, amplitude of wrist peak velocity was lower (see Fig. 2b), and height of the trajectory wrist was higher (see Fig. 2c) for the incongruent than for the congruent competition condition. For the grasping component, time of maximum grip aperture was later (see Fig. 3a) and amplitude of maximum grip aperture was smaller (see Fig. 3b) for the incongruent than for the congruent competition condition.

All in all these results suggest that the incongruent attitude of the actor model modified the kinematic pattern of the naïve participant. When in cooperation tasks the partner assumed a competitive attitude, the kinematic pattern of the naïve participant become more similar to a competitive than to a cooperative pattern (see Fig. 4). The opposite pattern was found when the incongruent attitude assumed by the actor model was cooperative (see Fig. 4). That is, when the incongruent attitude assumed by the actor model was cooperative (but the task was to compete), the

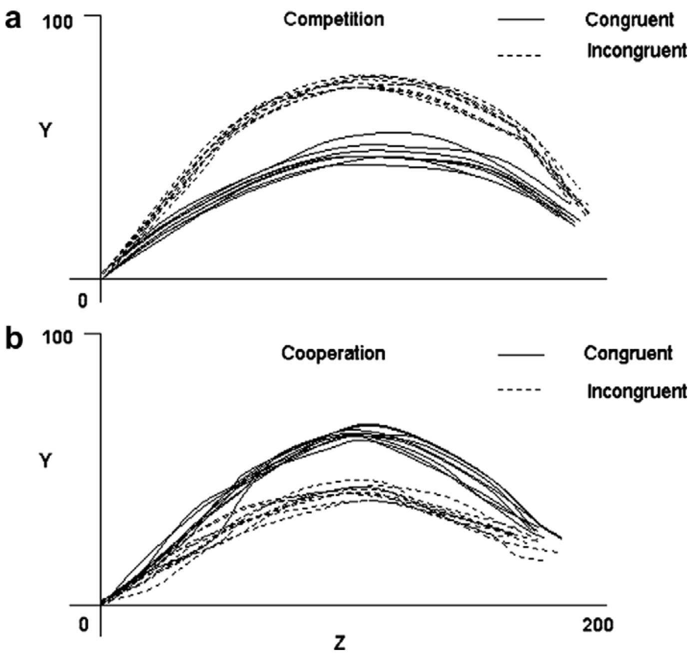

Fig. 4. Illustrated are spatial path trajectories for all ten trials of a representative subject (L.M.) for both the congruent and incongruent competitive (a) and cooperative (b) tasks. Bars represent the standard error.

Table 2

Pearson correlations within the couples (actor model and 12 naïve participants) for the congruent and incongruent cooperation and competition conditions with respect to time of max grip aperture (TGA), time to peak velocity (TPV) and time of maximum trajectory height (MTH)

Dependent Measures	TGA				MTH				TPV			
	Cooperation		Competition		Cooperation		Competition		Cooperation		Competition	
Couples	C	I	C	I	C	I	C	I	C	I	C	I
Actor model – P1	.85*	.22	.09	.88*	.65*	.31	.15	.27	.66*	.015	.28	.76*
Actor model – P2	.75*	.30	.16	.69*	.70*	.42	.23	.77*	.73*	.68*	.19	.88*
Actor model – P3	.54	.45	.22	.86*	.82*	.38	.42	.32	.59*	.21	.31	.92*
Actor model – P4	.68*	.64*	.31	.92*	.51	.27	.20	.85*	.41	.32	.28	.88*
Actor model – P5	.90*	53	.28	.68*	.66*	.80*	.17	.26	.77*	.48	.20	.92*
Actor model – P6	.45	.42	.42	.71*	.76*	.65*	.22	.71*	.87*	.51	.46	.27
Actor model – P7	.67*	.27	.38	.18	.82*	.24	.30	.82*	.78*	.46	.38	.77
Actor model – P8	.95*	.47	.51	.27	.75*	.35	.66*	.90*	.67*	.25	.40	.74*
Actor model – P9	.77*	.33	.43	.90*	.47	.22	.49	.21	.81*	.30	.48	.85*
Actor model – P10	.59*	.20	.37	.81*	.85*	.24	.36	.76*	.74*	.16	.35	.78*
Actor model – P11	.75*	.77*	.22	.78*	.68*	.76*	.41	.43	.68*	.27	.29	.18
Actor model – P12	.56	.72*	.17	.66*	.43	.46	.33	.62*	.72*	.31	.82*	.90*

Asterisks indicate significant correlations.

Notes. All significant at the 0.0001 level; C = Congruent; I = Incongruent.

kinematic pattern of the naïve subject became more similar to a cooperative than to a competitive pattern (see Fig. 4).

3.3. Correlation analysis

As previously demonstrated (Georgiou et al., 2006), all the parameters considered for this analysis revealed significant correlations between the movement of the agents for the congruent cooperative condition and no correlation for the congruent competitive condition (see Table 2). Interestingly, except for a few cases, for the incongruent cooperative condition such correlations were lost, whereas for the incongruent competitive condition significant correlations were found for the measures of interest (see Table 2).

4. Discussion

The main aim of the present study was to ascertain whether in a social context the kinematic parameters are influenced by the cooperative or competitive stance of the participants. To this end, we included an experimental manipulation intended to create a mismatch between task instructions and partner's attitude. In line with our predictions, the effects of such mismatch were evident on the kinematics of the naïve agent. In particular, cooperating with a partner displaying the intention to compete rendered the agent's action more competitive. The opposite effect emerged when competing with a partner displaying the intention to cooperate: the kinematic pattern of the agent became similar to a cooperative pattern.

These results complement and extend previous findings from our laboratory concerning the sensitivity of kinematics to prior intentions (Georgiou et al., 2006). We demonstrated that the planning and execution of a goal directed action is modulated by the intention of the agent to act in a social context. The present findings further extend the notion of a social dimension for cooperative and competitive behaviours. They demonstrate that kinematics is sensitive to the social intention displayed by the partner and do not simply reflect the *agent*'s intention. Paradoxically, both your intention and mine are reflected in the kinematics of my reach-to-grasp movement.

4.1. From motor to prior intentions: the influence of others' mental states on kinematics

The idea that the mental states of another's person can affect the agent's action was already present in the literature under the concept of motor interference (Castiello, 2003). In a series of experiments, an actor reached and grasped for an object presented in isolation or flanked by a distractor. Subsequently, an observer was required to perform a similar action toward the target object, but always in the absence of the distractor. The kinematics of both the human actor and the observer were affected by the presence of the distractor. Unexpectedly, similar effects were found in the observer's kinematics during the trials in which the actor was seated in front of the observer but no action was demonstrated. These findings were interpreted as evidence that even in the absence of any overtly executed action, other people's *motor intention* can influence the agent's kinematics.

The present study identifies new conditions for understanding the link between kinematics and mental states. If kinematics were simply sensitive to the others' action and motor intention, a similar kinematical pattern should be observed in the reach-to-grasp phase, regardless whether the attitude of the partner was congruent or incongruent with the task instructions. The existence of a difference between congruent and incongruent trials strongly suggests that the sensitivity of kinematics may extend beyond the others' motor intentions. In other words, influencing the kinematics of an agent's action is not only the action performed by the partner, but her prior intention, which can be inferred from her attitude.

4.2. Incongruent trials: implications for the explanation of the kinematic effects

A potential objection that could be made against this interpretation concerns the motor constraints imposed by the task. Could the differences in the kinematics of the agent simply reflect the motor constraints imposed by the task? Since cooperative and competitive actions may require different control strategies, it might well be that these strategies already emerged in the kinematics characterizing the reach-to-grasp phase (Georgiou et al., 2006). Whereas such explanation could account for the congruent conditions, an interpretation in terms of motor strategies does not hold for the incongruent conditions. This is because for the incongruent conditions the kinematics for the reach-to-grasp phase contrasted with the action subsequently performed by the agent during the interaction phase (i.e., cooperative or competitive). If kinematics simply reflected the adoption of a certain motor strategy, then no difference in kinematics should have been observed between reach-to-grasp movements preparing the same subsequent action.

The natural question concerns the mechanisms underlying the effect of the incongruent manipulation: what is it that causes the changes in the agent's kinematics on incongruent trials? What is the kinematics of the agent sensitive to?

Facial expression and body posture are important sources of information about conspecifics inner state (Allison, Puce, & Mc Carthy, 2000; Frith & Frith, 2006a). In the context of social interaction, they might allow an agent to anticipate what the partner is likely to do next, i.e., to infer her prior intention (Frith & Frith, 2006b). In this connection, a possible explanation of the incongruent manipulation effect reported here is that agents attributed to the partner an incongruent intention from the observation of these visual cues and this led to an automatic change in their kinematics. In this view, the changes in the kinematics of the agents would reflect the direct effect of the partner's attitude.

Another possible explanation is that the effect reflects a change in the actor's kinematics. For instance, during the incongruent cooperative conditions, the movement of the actor was already faster during the reach-to-grasp phase of the action. This decrease in the actor's movement duration could have plausibly influenced the participants' kinematics. The naive participant would simply mimic the movement of the actor. In this view, the reported effects might reflect a form of mimicry, i.e., the result of an automatic link between perceiving a behaviour and performing that behaviour (Chartrand & Bargh, 1999; Lakin & Chartrand, 2003).[1]

To summarize, there are two possible, non-mutually exclusive interpretations of the presented data, either an interpretation based on the actor's social attitude (facial expression and posture) which then influenced the participant's kinematics, or an interpretation based on a direct effect of the actor's kinematics on the participant's action.

4.3. Coordination between agents

A further issue to consider when interpreting these data is concerned with the action coordination between agents. We expected that disturbing the kinematics of the naïve agent would annul the correlations between key kinematic parameters for the incongruent cooperative task. Indeed, correlation analysis confirmed this prediction. Surprisingly, significant correlations in the movements performed by the two participants were chiefly observed for the incongruent competitive task. These findings may rule out the possibility that the incongruent manipulation produced a non-specific interference effect on the kinematics of the agent. In these circumstances no significant correlation should be observed for key kinematic parameters for the incongruent task. The very fact that we found significant correlations for the incongruent competitive task, but not for the incongruent cooperative task proves that the effect of the incongruent manipulation was intention-specific. The incongruent manipulation did not simply interfere with the execution of the agent's actions, but had the potency to induce a reversal in their kinematical patterning. As a result, cooperation in the form of action coordination was attained without being represented or intended as such.

Recently, Wilson and Knoblich (2005) proposed a possible mechanism by which action coordination in social contexts might be achieved. On the basis of the assumption that perceiving other people's behaviour activates imitative motor plans in the perceiver (Buccino, Binkofski, & Riggio, 2004; Grèzes, Armony, Rowe, & Passingham, 2003; Rizzolatti & Craighero, 2004) they suggest that these motor plans are used simultaneously for predicting the future course of others' action and for planning an appropriate complementary action.

This account implies that a rapid integration of self- and other-produced actions in real time can be achieved. Therefore, given the 'simultaneous' nature of our tasks it is tempting to speculate that the incongruent manipulation effect observed in our study is achieved through a similar real-time integration mechanism.

These findings have important implications for the interpretation of the influence of the partner's attitude in the context of social interaction. First, they shows how the attitude of the partner can have the potency to destroy cooperation (on incongruent cooperation trials), but also the effect to establish a cooperation (on incongruent competitive trials). Second, they provide evidence of a social dimension of coopera-

[1] We thank an anonymous reviewer for suggesting this alternative explanation.

tive behaviour exceeding the economic dimension. To explain, cooperating with a competitive partner might be extremely unfavourable in terms of outcomes: a mere economic explanation may thus account for the effect of attitude of the partner on cooperative incongruent trials. An economic explanation does not hold, however, for incongruent competitive trials. Compete with a cooperative partner might be in fact even more favourable than compete with a competitive partner. The fact that the kinematic pattern of the agent becomes nevertheless cooperative suggests that at least in some circumstances the attitude of the partner may prevail on the outcome.

Acknowledgements

This work was supported by a grant to U.C. from the Ministero dell'Istruzione, dell'Università e della Ricerca (MIUR). C.B. was supported by a grant from the CRT Foundation (Turin). The study had been approved by the local Ethics committee and written informed consent was obtained from each subject prior to participation.

References

Allison, T., Puce, A., & Mc Carthy, G. (2000). Social perception from visual cues: Role of the STS region. *Trends in Cognitive Science, 4*, 267–278.

Buccino, G., Binkofski, F., & Riggio, L. (2004). The mirror neuron system and action recognition. *Brain and Language, 89*, 370–376.

Castiello, U. (2003). Understanding other's people actions: Intention and attention. *Journal of Experimental Psychology: Human Perception and Performance, 29*, 416–430.

Chartrand, T. L., & Bargh, J. A. (1999). The Chameleon effect: The perception-behavior link and social interaction. *Journal of Personality and Social Psychology, 76*, 893–910.

Colman, A. M. (2003). Archaeology and cognitive evolution. *Behavioral and Brain Sciences, 26*, 139–153.

Decety, J., Jackson, P. L., Sommerville, J. A., Chaminade, T., & Meltzoff, A. N. (2004). The neural bases of cooperation and competition: An fMRI study. *NeuroImage, 23*, 744–751.

Dennet, D. C. (1996). *Kinds of minds*. Basic Books.

Frith, C. D., & Frith, U. (2006a). The neural basis of mentalizing. *Neuron, 50*, 531–534.

Frith, C. D., & Frith, U. (2006b). How we predict what other people are going to do. *Brain Research, 1079*, 36–46.

Gallagher, H. L., Jack, A. I., Roepstorff, A., & Frith, C. D. (2002). Imaging the intentional stance in a competitive game. *NeuroImage, 16*, 814–821.

Georgiou, J., Becchio, C., Glover, S., & Castello, U. (2006). Different action patterns for cooperative and competitive behaviour. *Cognition*, e-pub 3 March 2006.

Grèzes, J., Armony, J. L., Rowe, J., & Passingham, R. E. (2003). Activations related to "mirror" and "canonical" neurones in the human brain: An fMRI study. *Neuron, 18*, 928–937.

Lakin, J. L., & Chartrand, T. L. (2003). Using nonconscious behavioral mimicry to create affiliation and rapport. *Psychological Science, 14*, 334–339.

McCabe, K., Houser, D., Ryan, L., Smith, V., & Trouard, T. (2001). A functional imaging study of cooperation in two-person reciprocal exchange. *Proceedings of the National Academy of Science USA, 98*, 11832–11835.

Rilling, J. K., Gutman, D. A., Zeh, T. R., Pagnoni, G., Berns, G. S., & Kitts, C. D. (2002). A neural basis for social cooperation. *Neuron, 35*, 395–405.

Rizzolatti, G., & Craighero, L. (2004). The mirror neuron system. *Annual Review of Neuroscience, 27*, 169–192.

Searle, J. R. (1983). *Intentionality: An essay in the philosophy of mind*. New York: Cambridge University Press.

Shuster, R., & Perelberg, A. (2004). Why cooperate? An economic perspective is not enough. *Behavioural Processes, 66*, 261–277.

Trivers, R. L. (1971). The evolution of reciprocal altruism. *Quarterly Review of Biology, 46*, 35–57.

Trivers, R. L. (1985). *Social Evolution*. Menlo Park, CA: Benjamin/Cummings Publishing.

Tuomela, R. (2000). *Cooperation: A Philosophical Study. Philosophical Studies Series*. Dordrecht: Kluwer Academic Publishers.

Wilson, M., & Knoblich, G. (2005). The case for motor involvement in perceiving conspecifics. *Psychological Bulletin, 131*, 460–473.