Accepted on Psychological Research, November 25, 2011

Acting in perspective: The role of body and language as social tools.

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Abstract: 176 words.

Article length: 9266 words, including abstract, figures and references.

Figures: 4

Running title: It's just a matter of (social) perspective

***Keywords**: social perspective, social cognition, social affordances, language comprehension, words as tools, canonical and mirror neuron system.*

Abstract

We investigated how the reach-to-grasp movement is influenced by the presence of another person (friend or non-friend), who was either invisible (behind) or located in different positions with respect to an object and to the Agent, and by the perspective conveyed by linguistic pronouns ("I", "You").

The interaction between Social Relationship and Relative Position influenced the latency of both maximal fingers aperture and velocity peak, showing shorter latencies in presence of a non-friend than in presence of a friend. However, whereas the relative position of a non-friend did not affect the kinematics of the movement, the position of a friend mattered: latencies were significantly shorter with friends only in positions allowing them to easily reach for the object. Finally the investigation of the overall reaching movement time showed an interaction between the Speaker and the Pronoun: participants reached the object more quickly when the Other spoke, particularly if she used the "I" pronoun. This suggests that speaking, and particularly using the "I" pronoun, evokes a potential action. Implications of the results for embodied cognition are discussed.

Introduction

Literature on embodied cognition has grown exponentially in the last ten years, as some eminent scholars have recently underlined (Chatterije 2010; Gentner 2010). Despite the impressive amount of increasing evidence (for reviews, see Fischer and Zwaan 2008; Barsalou 2008), many issues are still open and will hopefully be solved in the next few years. One important issue concerns the role of the social dimension for cognition (Sebanz et al, 2006; Rueschemeyer et al. 2009).

Many behavioural and brain imaging studies (for a review, Martin 2007) demonstrated that observing objects activates action potentialities. In this sense, the term affordance, initially proposed by Gibson (1979), has been given new life also thanks to the extensive use of the notion of micro-affordance. Micro-affordances are specific reaching-grasping patterns adequate for interacting with objects, activated during object observation; they are the product of conjoining, in the brain, of specific visuomotor patterns (Ellis and Tucker 2000; Grèzes et al. 2003). Even if the continuity with Gibson is evident, in contrast with Gibson scientists are interested also in how micro-affordances are represented in the brain.

Many studies have investigated how affordances emerge in the relationship between organisms and objects. However, only a few have focused on how affordances are influenced by the context in which objects appear and actions occur. Context may be differently conceived: it can be considered as the specific condition given by the presence of other objects, either distractors (e.g. Ellis et al. 2007) or objects to be used together with the target (e.g., a fork and a plate) (e.g., Pezzulo et al. 2009; Yoon et al. 2010). Alternatively, context may be conceived as the "social context" in which actions occur: this aspect has been quite neglected in the study of affordances. This is true also for common social situations, such as the presence of other people when we interact with an object. This is striking, since the environment in which we live is filled with both objects and other organisms.

In the last years evidence has been reported, showing that the kinematics of reach and grasp movements with objects is modulated by the presence of another person in the experimental setting. Recent results from kinematics experiments appear in contrast with the predictions of the theory of social arousal, according to which the mere presence of other people enhances performance in a variety of task, due to a social facilitation effect (Zajonc 1965). While the social facilitation should affect different motor interactions in a similar way, these recent results showed that performance is affected only when a physical interaction occurs between two agents (for example, the agent passes an object to another person) (for an overview see Becchio et al. 2010). Becchio, Sartori, Bulgheroni and Castiello (2008) found that during the reach-to-grasp and placing phases kinematics are sensitive to social aspects, i.e. to the goal of passing an object to another person. Sartori, Becchio, Bulgheroni and Castiello (2009) studied the effect of an unexpected social request, i.e. a hand opening to express the willing to ask for the object, and found that this request interfered with the task of placing the object on a platform, deviating the trajectory of the movement toward the other. No perturbation of the normal trajectory was present with a robotic agent or when no communicative intention was conveyed.

Along the same line, other studies investigated a specific kind of interactive behaviour, the feeding behavior. Ferri Campione, Dalla Volta, Gianelli and Gentilucci (2011) compared the kinematics of reaching, grasping and placing a piece of food into the mouth of another person or into a mouth-like aperture. Results showed that, while interacting with another person, a special kind of interaction with the object is activated (social affordance), which leads to an increase of accuracy during the movement execution (slowing down of both the reaching and placing movement). The precondition for the activation of this higher accuracy is the fact that the recipient signals her willing to be fed, opening her mouth. The entire sequence of reaching-grasping and placing was affected even when the task was not finalized to feed but the other person opened the mouth, thus activating a social request.

Overall, these studies show that we respond to objects differently when we are on our own and when we interact with others. However, they typically contrast situations in which the individual is on her own with interactive situations such as passing an object or feeding someone. In addition, results suggest that the reach-and-grasp kinematics is affected only when the other person clearly signals her communicative intention, with different kinds of gestures – for example, opening the mouth to be fed, or stretching out the hand to signal the willingness to receive an object.

The setup of our experiment is rather different. Across conditions, a small cube was located on a table, within the participant's peripersonal space, and the participant sat in front of it. The characteristics of the object and its location were not manipulated, since we were interested in how the presence of another person influences the participant's actions upon the object. For this reason, we manipulated the mutual position of two participants with respect to the object one of the two (from now on Agent) had to act upon. Indeed, a second participant (from now on Other) was either invisible (behind) or located in different positions with respect to the object and to the Agent: she could sit in front of the participant, either close or far from the table (frontal-near vs. frontal-far), or she could sit on the participant's right or left side. In the latter cases the Other shared both the perspective and the peripersonal space with the participant, in the frontal-near condition she shared with her the peripersonal space, and in the frontal-far condition she did not share with the other neither the perspective nor the peripersonal space. In addition, we manipulated the perspective as linguistically conveyed by pronouns. Both the Agent and the Other were required to pronounce sentences such as "I / YOU grasp/take", using the first vs. second person pronouns. Importantly, while both participants spoke, only the Agent acted to reach and grasp the small cube in front of her.

A first difference from previous studies is that in our case neither the instructions nor the situation invited participants to directly interact with the Other through the object (e.g. passing an object, feeding another person), performing a joint action: participants had to move the object on their own, even if in presence of another person.

A further difference from previous studies is that in our work the intentions of the other person were not expressed through communicative gestures. Rather, these intentions could be only inferred from different variables we manipulated to characterize the Other and his/her presence, that is:

1) the distance between the Other's body and the object (the object could be either in the peripersonal or extrapersonal space of the Other), and her perspective with respect to it (frontal, left, right): variable Relative position. This

manipulation defined different types of potential interaction between Agent and Other, even though an actual interaction is not allowed. Relative spatial position and perspective are thus considered as aspects of social interactions which may convey social intentions.

2) the type of relationship between the two participants: in fact, they could be already friends or see each other for the first time during the experiment: variable Social Relationship. Relationship conveyed the status of the relationship outside the experiment and the eventual previous social interactions, that could modify the way local interactions and social intentions were perceived by the participants themselves.

3) the linguistic expressions the participants were required to use. Either the Agent or the Other could assume the role of Speaker (variable Speaker), and they could use either the first or second person pronoun ("I", "You", variable Pronoun) to accomplish the linguistic task. Assuming the role of speaker as well as using a 1st (vs. 2nd) person pronoun typically convey communicative social intentions; our manipulation allow to scrutinize the strength of each of the two linguistic variable also in a mismatch condition.

Below we will address these 3 issues separately.

1) Relative Position.

Affordances are activated primarily when objects can be easily reached, rather than when they are in subjects' extrapersonal space (Costantini et al. in press-a, Costantini et al., in press-b). Crucially for us, Costantini et al (in press-a) demonstrated that affordances are also activated when objects are located in the peripersonal space of another person (e.g. an avatar instead of an inanimate cylinder). This result, which suggests an important role played by the mirror mechanism (Gallese et al. 1996), indicates that seeing another person close to an object evokes the objects affordances, together with the simulation of her potential interaction with the object.

On this basis, we predict that the perspective of the other with respect to the object will influence the reach-grasp kinematics. Specifically, if through the mirror system participant simulate that the Other might interact with the object, a different pattern should be observed when the object is located in the Other's peripersonal space compared to when it is out of her reach. In addition, when the object is in the Other's peripersonal space, the Other's perspective with respect to the Agent (frontal, on the right, on the left side) should influence performance. Indeed, objects should be grasped more quickly in the frontal and left-side perspective (respective to the Other), less quickly in the right-side perspective, since when the Other is on the Agent's right her dominant hand is more distant from the object than in the two other perspectives.

2) Social Relationship.

The kinematics of the interaction with an object can be modified on the basis of the social relationship existing between individuals. Evidence has revealed that the relationship existing between participants influenced performance. For example, Georgiou, Becchio, Glover and Castiello (2007) showed that specific kinematics patterns were present when participants had to cooperate vs. to compete with others and when participants were on their own. In a similar vein Ferri, Stoianov, Gianelli, D'Amico, Borghi and Gallese (2010) demonstrated that the kinematics of the feeding behavior was modulated by the facial expression of the recipient, and that participants were more accurate when they used the mouse to simulate feeding a happy face compared to a disgusted, neutral or sad face.

However, to our knowledge nobody has directly investigated how a long term relationship can influence self-generated goal-directed actions, such as reach-and-grasp of objects kinematics. Due to the difficulty to operationalize this variable (Rivas 2009; Helbing and Yu 2009), we chose people that know each other from at least two months and that see each other at least once for week. We predicted that the kinematics of movement would be affected by the social relationship between participants, in particular producing slower and more accurate movements in presence of friends, as an effect of a cooperative attitude towards friends as compared to non-friends. Since we also manipulated the spatial relationship between the two participants during the experiment, we expected that the Relative Position and Social Relationship would specifically interact producing different kinematics pattern.

3) Speaker and Pronoun.

Our interest focused on two aspects. First, we intended to verify whether speaking can be considered as a form of action. If this is the case, then the Other should have a stronger influence on performance when she is a speaker than when she is not. This condition could then replace the actual interaction that other studies used to evaluate how movement execution is influenced by other people. Second, if it is true that we form a simulation during language comprehension and production (Gallese 2009; Borghi et al. 2010; D'Ausilio et al. 2009; Binkofski and Buccino 2009; Pulvermüller and Fadiga, 2010), then we should find a different effect when the simulation involves the first and the second person (conveyed by "I" or "You" pronoun) depending on the speaker's perspective. In this sense we expected that Speaker and Pronoun would interact in affecting the motor performance of the Agent, since the role of the Speaker was assumed also by the Other.

Method

Participants

Twenty-four students divided into twelve couples took part in the experiment (mean age 21.71, SD = 3.25; 12 women). Each couple could be either formed by two students already knowing each other or by students who never met before. For each couple gender was randomly mixed and two roles were randomly assigned: Agent and Other (each person in the couple was used *only* as Agent or Other for all the experiment). All were right-handed, native Italian speakers with normal or corrected-to-normal vision and were naive as to the purpose of the experiment. The study was carried out along the principles of the Helsinki Declaration and was approved by the local ethics committee.

Apparatus and stimuli

The Agent sat in front of a table where a small wooden cube (3x3 cm) was placed at a distance of 40 cm. The participant sat holding the hand in pinch position before each trial. The Other could be placed in five different spatial positions with respect to the Agent: (1) on the right side, (2) on the left side, (3) frontal, near to the Agent, (4) frontal, far from the Agent, (5) behind the participant and thus not visible (see fig. 1a). Each spatial position involved a different spatial relation between the agents and the target object. In (1) and (2)

the two participants shared perspective and reaching space, in (3) participants shared the reaching space but not the perspective, while in (4) they did not share neither the reaching space nor the perspective, as in (5), with the additional loss of direct visual contact.

The spatial positions defined five blocks of 16 trials, whose order was randomly assigned for each couple. The Other sat in the assigned position with the hand in pinch position, symmetrically to the Agent.

Insert Figure 1 about here

Procedure

Before each trial participants were required to close and then to open their eyes (the right execution of the task was controlled in turn by one of the two experimenters). Then, the instruction to conjugate a verb ("to take", "to grasp"), with the pronoun "I" or "You" was given to either the Agent (named "X" during the experiment) or to the Other (named "Y"): "X conjugate the verb to take, first person" (*see* fig. 1b). The two verbs were chosen for the motor similarity of the two actions they describe and in order to avoid the repetition of a single verb. For this reason, the two verbs were not considered separately and there was no further manipulation, since no difference between the two verbs was expected. The linguistic production task was shared by the two participants, who could be equally addressed by this instruction in each trial. The motor task to reach and grasp the target cube, instead, was assigned only to the Agent. Then, once conjugated the verb, the Agent was asked to reach and grasp the cube in front of her and then to come back to the starting position.

The task was then two folded: while the Agent had always to grasp the cube while being speaker or listener, the Other could act only as speaker with no possibility to act directly. Before each session, the two participants filled in a questionnaire, requiring to indicate whether they knew each other or not, and, if yes, to rate how often they meet (scale 1-5, from everyday to less than once a month) and how deep they found their relationship (scale 1-7). At the end of the session, a de-briefing phase followed, where each participant – and specifically the active Agent – was required to describe her experience during the experiment. The de-briefing was divided into two parts: the first, where both the participants were asked to report their impressions and to describe their first-person experience of the task; the second, a free discussion where participants were asked to report their impression answering to three main questions concerning the most crucial aspects of the task: the perceived difference between the left and right positions, between the frontal-near and the frontal-far position, and the perception of the difference between being speaker-agent and listener-agent (the question will be reported in the results section).

Data Recording and Analysis

Movements of the participant's right hand were recorded using the 3D-optoelectronic SMART system (BTS Bioengineering, Milano, Italy) by means of four video cameras detecting infrared reflecting markers at a sampling rate of 120 Hz and spatial resolution of 0.3 mm. Recorded data were filtered using a linear

smoothing rectangular filter. Participants were informed that their movement was recorded and they were asked to perform the movement as naturally as possible. Three reflecting markers were used to record the participants' right hand. Two markers, applied on the tip of the index and thumb fingers, were used to evaluate the grasp component of movement through the time course of the distance between index and thumb. The last marker was applied on the wrist to analyze the reach component of movement.

The distance between the thumb and the index finger was used to determine onset (o_g) and termination (t_g) of the grasping component of the movement (defined by the distance crossing a threshold of 5%); wrist velocity was used to determine onset (o_r) and termination (t_r) of the reaching component (defined by the tangential velocity crossing a threshold of 5% of peak velocity). As some participants started to move the fingers before the wrist, the onset of the overall movement execution was defined as the first kinematics event (o_g or o_r); symmetrically, the end of the overall movement corresponded to the last kinematics event (t_g or t_r). We used the movement execution time to define the respective distribution of the grasp and reach components, measuring the Reaching Time with respect to the overall movement time, i.e. *percentage* of Reaching Time. The ratio between the duration of the reaching phase and the total movement duration was calculated in order to normalize the values to make comparison between subjects also on relative timing (for a similar choice to express temporal data also as a percentage of total movement duration see Marteniuk, Mackenzie, Jeannerod, Athenes, & Dugas, 1987; Jakobson & Goodale, 1991; Patchay, Castiello & Haggard, 2003; Bensoussan, Mesure, Viton & Delarque, 2006; Maslovat, Hodges, Chua & Franks, 2011)

Taking into account the grasp and reach components separately, we decided to focus on kinematics parameters already known to be affected by social cues. The grasping was characterized by the key parameter of latency of maximal fingers aperture (time between the grasp beginning and maximal finger aperture). Similarly, the latency of velocity peak was considered as the crucial parameter for the reaching component (corresponding to the time to reach the velocity peak during the accelerative phase). These parameters have been shown to be modulated by social cues (see Becchio et al. 2008a, 2008b; Georgiou et al. 2007; Ferri et al. 2010, 2011) since they are modulated by variations in movement speed. Specifically, these parameters should be modulated according to the type of social interaction occurring between two participants and to the kind of involvement of the two in the social interaction (i.e. cooperative vs. competitive behavior).

Kinematic parameters

Our dependent variables were: (1) latency of Maximal Fingers Aperture (lMFA); (2) latency of Velocity Peak (lVP); (3) Reaching Time respective to the overall movement (%RT).

All variables were submitted to a 2 (Social Relationship: Friends *vs.* Non-Friends) X 5 (Relative Position: Right-side vs. Left-side vs. Non-visible Other vs. Frontal-near vs. Frontal-far) X 2 (Speaker: Agent *vs.* Other) X 2 (Pronoun: "I" *vs.* "You") ANOVA; the variable Social Relationship was manipulated *between* participants. The data were controlled for multiple comparisons using Bonferroni

correction, yielding a significance level of (0.05/3, dependent variables) 0.02 for each single comparison.

Results

1. Latency of Maximal Fingers Aperture (lMFA)

Analyses on latency of Maximal Fingers Aperture did not show significant main effects (Social Relationship: $p = .03$; Relative Position: $p = .31$; Speaker: $p = .53$; Pronoun: $p = .67$). Interestingly, the interaction between Social Relationship and Relative Position was significant, F (2, 40) = 3.69, MSe = 14001,98, $p < .01$: in presence of a non-friend the latency of maximal fingers aperture was shorter than in presence of a friend in all the five Relative Positions (post-hoc LSD-test: $ps < .005$). Whereas the relative position of a Non-friend did not affect the lMFA, the relative position of a Friend mattered. If the Friend was in reaching distance in the near front position or non-visible the lMFA was shorter (frontal-near: M = 979.69 ms; non-visible: M = 981.81 ms) than when she was in reaching distance on the right of the participant (M = 1084.34 ms, post-hoc LSD-test $ps < .02$) or in the no reaching distance (frontal-far, M = 1070.87 ms, post-hoc LSD-test $ps < .02$) (*see* Figure 2a). Finally we found an interaction between Relative Position and Speaker, F (2, 40) = 2.95, MSe = 3444.50, $p < .03$: interestingly, the shortest latencies emerged when the speaker was the Other and she was located in the frontal-near position (M = 891.36 ms); post-hoc LSD-test showed that in all the relative positions there were no differences in latencies between the Speaker-*Agent* or Speaker-*Other* conditions except in case of the Other located on the right (as in this condition maximal fingers aperture occurred earlier: Speaker-*Agent*: M = 969.73 ms; Speaker-*Other*: M = 925 ms, $p < .02$) (*see* Figure 2b).

Insert Figure 2 about here.

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2. Latency of Velocity Peak (lVP)

As to the latency of Velocity Peak (lVP), analyses did not show significant main effects (Social Relationship: $p = .13$; Relative Position: $p = .93$; Speaker: $p = .22$; Pronoun: $p = .65$). Crucially the interaction between Social Relationship and Relative Position was significant, F (2, 40) = 2.71, MSe = 4714.66, $p < .04$: latencies were shorter with non-friends than with friends for all the positions (Non-friends: *right-side* M = 420.36 ms; *non-visible* M = 435.12 ms; *frontal-far* M = 440.60 ms; *frontal-near* M = 438.74 ms; Friends: *right-side* M = 507.67 ms; *non-visible* M = 487.77 ms ; *frontal-far* M = 506.81 ms; *frontal-near* M = 438.74 ms; post-hoc LSD-test: $ps < .02$), except for the left-side position. It's worth noting that absence of difference between Non-Friends and Friends in this condition (Non-friends M = 466.71 ms, Friends M = 464.58, $p = .91$, *see* Figure 3) is mostly due to shorter latencies for Non-friends located on the right-side compared to the left one ($p < .03$), and partially to shorter latencies for Friends located in the left-side compared to the right one ($p = .054$).

Insert Figure 3 about here.

3. Reaching Time (%RT)

Analyses on the percentage of Reaching Time respective to the overall movement did not show significant main effects (Social Relationship: p = .83; Relative Position: p = .83; Speaker: p = .51; Pronoun: p = .21). We found a significant interaction between Relative Position and Pronoun, F (2,40) = 3.10, MSe = 16.09, p < .03: post-hoc LSD-test showed that for all the five relative positions there were no differences between the "I" and "You" pronoun (post-hoc LSD-test: *ps* >= .12), except for the other located on the right of the agent, as in this condition the percentage of movement time devoted to the reaching was smaller for the "I" (M = 91.43 %) than for the "You" pronoun (M = 95 %, p < .005; *see* Figure 4a). Notably, we found also a significant interaction between Speaker and Pronoun, F (1, 10) = 10.57, MSe = 6.31, p < .01: post-hoc LSD-test showed that when the Speaker was the Other, a smaller percentage of movement time was dedicated to the reaching phase if the used pronoun was "I" (M = 93.04 %) than "You" (M = 94.55 %, p < .01); when the Agent was also Speaker there was no difference between the "I" and "You" pronoun (p = .19, *see* Figure 4b).

Insert Figure 4 about here.

Debriefing

As discussed in the methods section, we chose for a semi-structured de-briefing phase, thus we relied only on qualitative personal impressions of the participants and not on quantitative scores.

(1) "Did you feel a difference between left and right positions, and if so did you feel one of the two as more invasive for you?". All the couple except one reported to have perceived no difference between the left and right side. (2) "How did you feel in the case of the frontal position? Did you notice any difference between the far and near position? Did you use any strategy in those cases?" The frontal position was explicitly perceived as "different" by large part of the couples (9/12). Interestingly, the frontal position was considered more "invasive", with no great distinction between the far and near position. The couples reported different strategies used to avoid this "invasion": some completely avoided eye contact; others looked explicitly for the eye contact. (3) "Did you perceive (as Agent) any difference between the condition of being speaker-agent and listener-agent?" Large part of the Agents (9/12) reported a different between the "I-You" speaking conditions. Of those who reported a difference, five felt a facilitation in movement execution when they were speakers, and specifically using the "I" pronoun.

Discussion

One key issue for embodied cognition is to understand how the way we interact with objects is influenced by the constraints given by our own physical body and by the physical and social context. Our results clearly showed that not

only our body, the body of others and their position with respect to us and to objects, but also the social relationship with other people, influence actions. The pattern of results reveals that the reach-to-grasp kinematics is affected by the variables we identified (Relative Position, Social Relationship, Speaker and Pronoun), in a complex interplay.

First, we found an interaction between Social Relationship and Relative Position in parameters concerning the early phases of both reaching and grasping, such as the maximal wrist velocity and the time to maximal fingers aperture. The pattern of results was rather straightforward.

As to the wrist velocity, the latency of velocity peak was shorter with Non-Friend than Friends, but we did not find any difference when the Other was on the left-side. Shorter latencies were found with Non-Friends if the other was on the right-side compared to the left one; Friends showed an opposite pattern, even if only in trend. It seems that Non-Friends are perceived as more dangerous on the right-side, inducing a competitive attitude in the Agent and thus shortening the latencies of velocity peak. The shorter latencies in case of Friends located on the left side, as compared to the right one, could be due to a completely different mechanism: the presence of a well known person in the left position may favor the simulation of an action of transfer, to reach and grasp the cube to give it to a person with which I usually share things. With a Friend on the right-side the transfer movement is prevented by biomechanical constraints; nevertheless, when on the right friends were not yet seen as potentially dangerous with respect to the object, for two probable reasons. First, the Other's right hand was rather distant from the object. Second, since the Agent used the right hand to respond, the shoulder and the arm protected her from the Other.

The data on latency of maximal fingers aperture were consistent with those found on the latency of velocity peaks . The interaction between Social Relationship and Position suggests that maximal finger aperture occurred earlier with non-friends than with friends, probably because the Agent interpreted the Other as a potential competitor with respect to the object. This interpretation is supported by the data obtained when friends were present. Friend was considered as potential competitor when a) she was in a position allowing to easily reach for the object (*shared peripersonal space*) and b) the direction of movement the Agent was required to perform (*towards her body, away from the other's body*) does not allow for a transfer movement. This explains why the latencies were shorter in the frontal-near than in the frontal-far condition. Interestingly we found short latencies also in case of Friends non-visible, particularly in the grasping component of the movement: when the other is not visible I do not have to adapt the motor program to a specific body (with which to interact / against which to compete); as a consequence the reaching and grasping movement is executed more quickly.

These findings confirm previous evidence on activation of affordances in the peripersonal space of others (see Costantini et al. 2010a). Participants seemed to predict that, when the Other is close to the object, she may try to grasp it. Indeed, when they perceived friends as close to the object, they activated a faster response. When friends were in the frontal-far and right-side conditions, latencies were longer, probably because from these positions the object could not be easily reached by the Other. That is, not just variations in Other's movements vehicle social messages (Daprati et al. 2011), but also her relative position with respect to our own body. One could ask why we found a modulation of the latency of maximal fingers aperture due to the Relative Position only with friends. Our data

leave two possibilities open: the first is that an unknown person is always perceived as a potential competitor in this task, thus provoking faster responses independently of the position; Friends, instead, are perceived as competitors only when they are close to the object. The second is that we found a modulation due to the position only with friends due to the very fast responses triggered by unknown Others.

Second, we found that Relative Position interacts with language in key parameters related both to the reaching (%RT) and the grasping phases. The interaction between Relative Position and Speaker in the latency of maximal fingers aperture revealed that the shortest latencies were obtained when the Other was frontal-near to the agent, and spoke. This result, which is quite novel, suggests that the simple fact of speaking can be considered as a form of action; the action of speaking increases the visibility and the potential "danger" of the Other. This is testified also by the fact that when the Other is on the right-side and became a speaker, then maximal fingers aperture occurred earlier, as if language would increased the visibility of the person. Similarly, when the Other was on the right-side and the pronoun "I" was used, responses were faster, as the interaction between Position and Pronoun on %RT revealed.

Third, the idea that language is a way to act and to direct attention is further supported by the interaction we found between Speaker and Pronoun, characterizing the reaching phase. The interaction between Speaker and Pronoun in the %RT reveals that, when the Other was speaking, the percentage of movement time devoted to the reaching phase was shorter with the "I" pronoun. Notice that, when the Other used the "I" pronoun, no action of the Other followed. In spite of this, it seemed that participants predicted that the Other would interact with the object, and this speeded up their reaching responses.

In sum: our findings indicate that the reach-and-grasp kinematics is influenced by the bodily position of the Other with respect to the object, even if no physical interaction between the two individuals takes place. Below we will discuss possible implications of our study for embodied cognition.

Affordances. Our study questions the idea that affordances are only individual action opportunities. Rather, results suggest that responses to objects are influenced by the complex social and physical context in which they are embedded (Richardson et al. 2007).

Others' bodies and intentions. Our results reveal that not only we understand others as goal-directed, intentional agents (Tomasello et al. 2005), but that we interpret others' implicit social intentions from their distance in space from objects and from us. Even if they do not act, from their bodily position we infer their potential actions (for similar results, Tversky and Hard 2009), and this simulation affects actions planning.

Friendship. Our results indicate that all actions are modulated by the presence of others, even when no physical interaction with others occurs. The presence of another person does not indistinctively enhance participant's performance, as the social facilitation theory would suggest. Instead, behavior is modulated by the presence of another person in complex and sophisticated ways. Participants are sensitive to friendship: they are less afraid to share their space with friends; with friends they are more accurate, and compete less for the possession of objects than with unknown others. How individual/relational characteristics influenced the individual strategies of cooperation and competition both in primates and humans (for reviews see Smith 1996; Massen et al. 2010), has been mostly investigated in the areas of social science (Silk 2003; Helbing and Yu 2009), cognitive

development (Hartup 1996), games theory (Rivas 2009) or behavioral biology (Lyons and Aitken 2008). In cognitive psychology recent studies on the Social Simon Effect demonstrated that socially shared task representations are modulated by a positive vs. negative relationship, induced by a cooperative vs. competitive confederate (e.g., Hommel et al. 2009). However, the majority of the studies focuses on cooperative/competitive relationships built during the experiment. To our knowledge, this is the first study that reveals different effects of long-term relationships on reach-and-grasp kinematics.

Language and simulation. According to embodied theories during language comprehension the same perception, action and emotional systems are recruited, which are at play during interaction with objects and with others. Evidence has successfully demonstrated that concrete words, such as "telephone", activate multimodal experiences with their referents, and that action words activate the motor system in an effector specific way (for reviews, see Barsalou 2008; Fischer and Zwaan, 2008; Gallese 2009; Toni et al. 2008). Our results support this view. The effects of the bodily position are stronger and the competition effects are enhanced when the Other uses language, and particularly the pronoun "I". Even if participants know that, when the Other pronounces the pronoun "I", no action will follow, still they can't help speeding up their responses with the first person pronoun. This suggests that listening to the "I" pronoun followed by the verb "take" evokes an automatic prediction of the action that may follow..

Words as tools. In the attempt to contrast propositional views of language, scholars adopting an embodied cognition view have privileged a referential view of language. This had led them to somehow neglect the acquisition of the philosophical and pragmatic literature, according to which words can be considered as tools (Borghi and Cimatti 2009, 2010; Clark 1998). Words are tools both because they might help us act on our environment and they are forms of action, because they might change the other's mental states (Tylen et al. 2010). A demonstration that words are tools even comes from evidence showing that words lead us to perceive objects as more close to us than they are in reality (Scorolli et al. 2010). In this work we found that words are tools as they play a twofold role. When the Other is the speaker, she is perceived more distinctively as a potential competitor: this testifies that words are instruments that orient our attention. Furthermore, using words, but particularly using the verb "take" in combination with the pronoun "I", is intended as an action, and it speeds up the response.

Egocentric perspective. Brain-imaging studies on action observation have shown that different areas of the posterior parietal cortex are specialized for egocentric and non-egocentric perspectives (Jackson et al. 2006; Schütz-Bosbach et al. 2006). Behavioural evidence on action observation complements these findings, confirming an advantage for the egocentric perspective when we perceive hands of others in our own or in an allocentric perspective (Vogt et al. 2003; Gianelli et al. 2008; Bruzzo et al. 2008; Marzoli et al. 2011). These findings can be been interpreted in favor of the common coding theory (Prinz 1997; Hommel et al. 2001), as they show that the similarity between the observed actions and the actions which are part of our motor programs enhances recognition (Bruzzo et al. 2008). In our results the absence of an advantage of the conditions in which the Other shares participant's perspective (being either on her left or right side) over the frontal conditions cast some doubts on the hypothesis, that we use our own body to simulate Other's actions (for a similar critique related to bodily posture, see Fischer 2005). Participants respond faster, when they perceive others as "menacing" the object, not when they share the same

perspective of others. It is possible that different mechanisms are at play while observing others: an egocentric perspective advantage, present mainly while observing pictures of other's hands (see Vogt et al. 2003), and an advantage for the other perspective, in presence of "real" others, based on the fear that they might grasp for the object.

Perspective and embodiment. To our knowledge only few studies focused on the perspective as given by the bodily posture (e.g. Kessler and Rotherford 2010a,b.). Flavell, Green and Flavell (1986) distinguished between two levels of visuo-spatial perspective taking (VPT): the first concerns the comprehension of what lies within somebody's else line of sight (in front of vs. behind, VPT-1), the second implies some form of mental rotation (e.g., aimed at determining that an object is on the right of another object from somebody's else point of view, VPT-2). VPT-1 develops earlier, around 2 years of age, and is characteristics of primates as well (Tomasello et al. 2005); VPT-2, instead, is more complex, develops later and children with autistic spectrum disorder experience some difficulties with this kind of VPT (e.g., Hamilton et al. 2009). In a recent behavioral work Kessler and Rutherford (2010a, 2010b) have shown that, while both VPTs are situated, a different kind of embodiment is subtended from the two perspectives. Indeed, they showed that VPT-1, a process consisting in determining the visibility of a target from a visual perspective, is not influenced by angular disparity of movement simulation. In contrast, VPT-2 is embodied as it involves the mental simulation of a bodily movement. We used a rather different paradigm, and did not require participants to explicitly adopt another person's perspective. However, our results have implications concerning the distinction between VPT-1 and VPT-2. In line with Kessler and Rutherford, we found differences between the two perspectives: for example, language (implying a clarification of others' intentions) seems to play a major role for the left-side and right-side positions, consistently with their higher complexity. However, our results suggest that also VPT-1 (in front of) is embodied and implies a simulation, as the Agent perform differently depending on whether the Other is in front of near vs. in front of far from the object.

Perspective and language. Only a few studies have focused on perspective during language processing and specifically from an embodied point of view (Gianelli, Farnè, Salemme, Jeannerod, & Roy, in press; MacWhinney, 2005). Here we were not interested in perspective pertaining the objects with respect to us (e.g., Borghi et al. 2004; Kaschak, Madden and Zwaan 2005), but rather in the perspective as implied and induced by the linguistic pronouns. Recently, Brunyé, Ditman, Mahoney, Augustyn, & Taylor (2009) showed with a picture-verification task that participants automatically activate an internal perspective when directly addressed as agents, i.e. when the "you" pronoun is used, while they activate an observer perspective with the "He" and "I" pronouns. In their study the linguistic perspective is directly matched with a visual perspective. The contribution of our study lies then in investigating the combined effect of the two forms of "social perspective", the perspective induced by the pronoun ("I", "You") and the perspective conveyed by the Other's body position and distance from the object. Our study adds to the previous evidence also because it shows cases in which there is a mismatch between the pronounced pronoun, and the agent. Even in such cases, when the Other pronounces the pronoun "I" and no action from her side follows, participants produce faster responses, probably due to the fact that they predict the subsequent action.

Social cognition. Our work suggests that the social dimension is really pervasive. Even if organisms act with objects on their own, they are influenced by the presence of others. The fact that the social relationship modulates kinematics parameters, suggests that the effects we found are intrinsically social, and cannot be simply due to the presence of a distractor (Ellis et al. 2007; Caligiore et al. present number). Furthermore, it suggests that the presence of others activates different kinds of mechanisms, which seem to be automatically and concurrently at play. Participants take into account the specific kind of relationship they have with others, and are more accurate and relaxed with friends. At the same time, results suggest that participants are not collaborative, but rather competitive towards the others. However, a different possibility is open. Participants are required to perform a task, in which no joint action is required; thus the other can be perceived as a potential obstacle with respect to the task, socially negotiated with the experimenter. In spite of the results of this study, we believe that further studies should consider both the social relationship between participants and between participants and the experimenters.

One final note concerns the method. Compared to response times, kinematics measures allow researchers to detect how the different action components are modulated, for example by the presence of others. Here parameters concerning both the early reaching and the early grasping phases were affected by the social dimension. Overall, results strongly suggest that the social dimension is at the core of human cognitive activity, more than it was proposed within the embodied literature so far (see Semin and Smith 2008, for a similar position). Further research is needed, to better and further investigate the complex interplay between our body, the physical and social environment in which it is embedded, and our cognitive activity.

Acknowledgments

The first two authors contributed equally, and the order of their names was randomly selected. The first two authors designed the experiment, conducted the experiment, analyzed the data and wrote the paper. The third author designed the experiment and wrote the paper.

This work was supported by the European Community, project ROSSI: Emergence of communication in RObots through Sensorimotor and Social Interaction (Grant agreement n. 216125).

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Figure Captions

Figure 1.

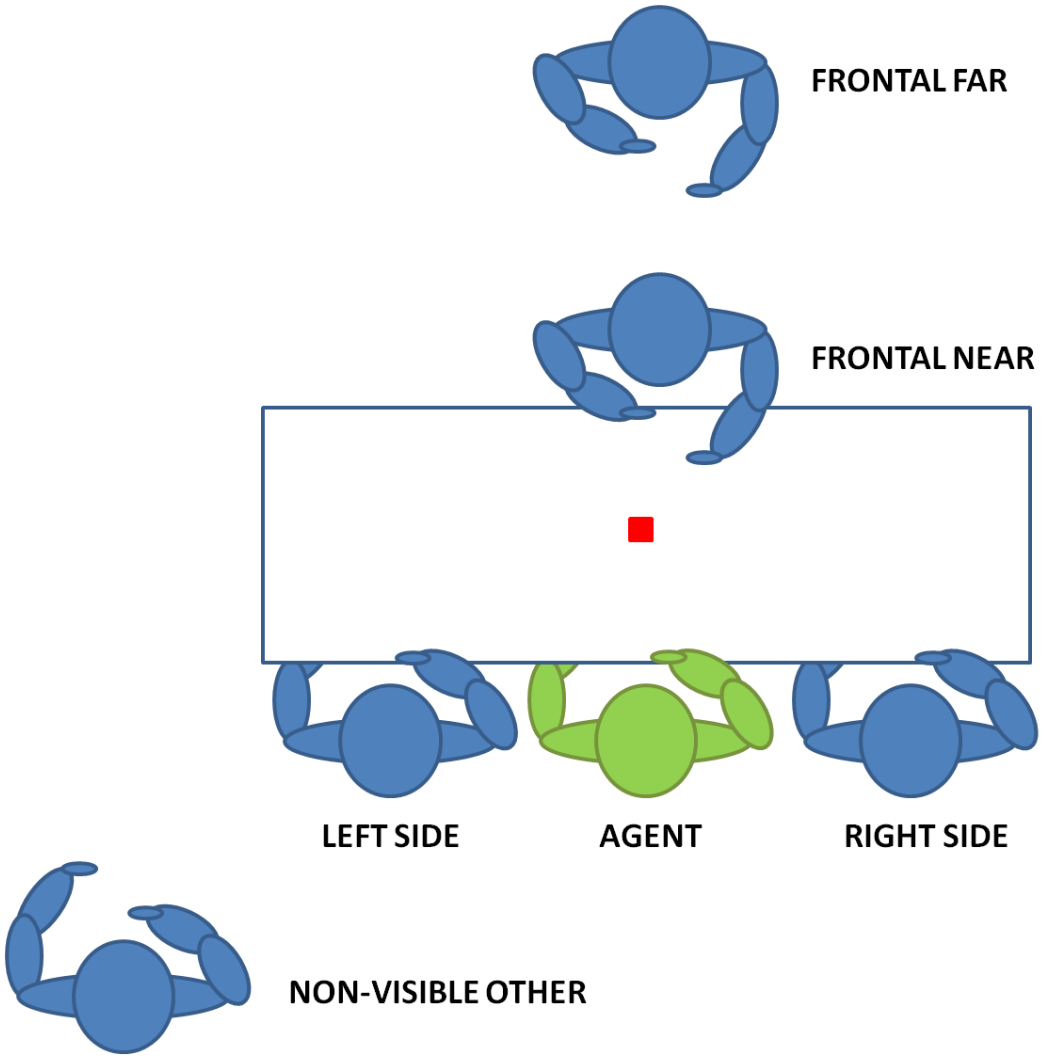
(a) The Agent sat in front of a table; a small cube was placed in the middle of the table at a distance of 38 cm. The Other could be placed in five different spatial positions with respect to the Agent: (1) on the right, (2) on the left side, (3) frontal-near, (4) frontal-far, (5) behind the participant and thus not visible. The distances between the body's midline of the Agent and the Other for each spatial position are indicated in cm.

(b) The paradigm. The experimenters instructed either the Agent (named X during the experiment) or the Other (named Y) to conjugate a verb ("to take", "to grasp") with the pronoun I or You to: "X conjugate the verb 'to take', first person".

Figure 2.
(a, b) Latencies to maximal fingers aperture: interaction between Social Relation and Relative Position (a); interaction between Relative Position and Speaker (b). Error bars represent the standard error.

Figure 3.
Latencies to velocity peak: interaction between Social Relation and Relative Position.

Figure 4.
(a, b) Reaching time -respective to the overall movement: interaction between Relative Position and Pronoun (a); interaction between Speaker and Pronoun (b).


FRONTAL FAR
FRONTAL NEAR
LEFT SIDE
AGENT
RIGHT SIDE
NON-VISIBLE OTHER

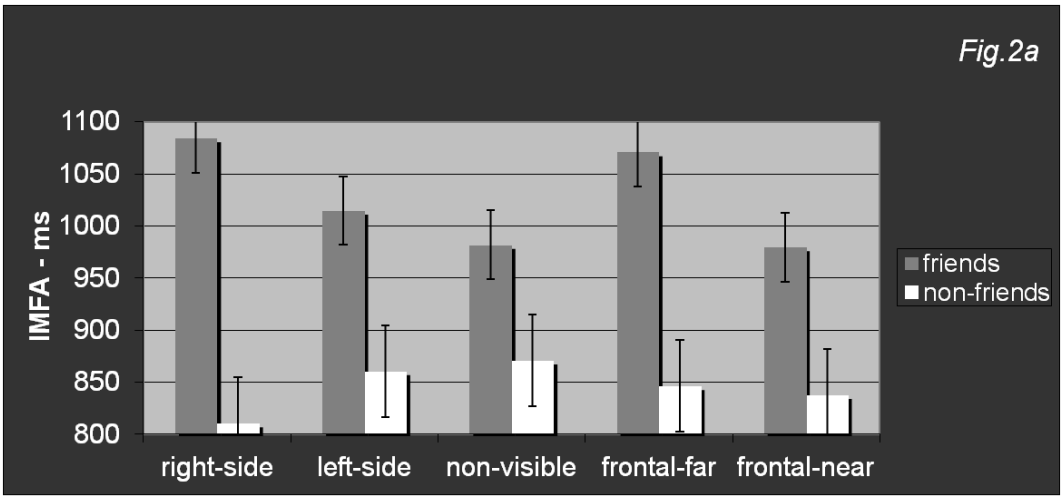


Fig.2a
IMFA - ms
1100
1050
1000
950
900
850
800
right-side
left-side
non-visible
frontal-far
frontal-near
friends
non-friends

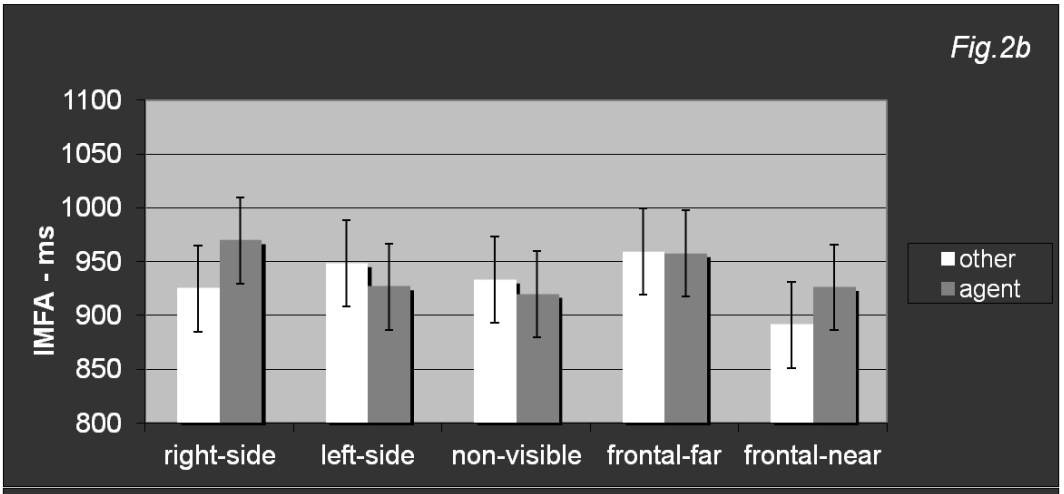


Fig.2b
IMFA - ms
1100
1050
1000
950
900
850
800
right-side
left-side
non-visible
frontal-far
frontal-near
other
agent

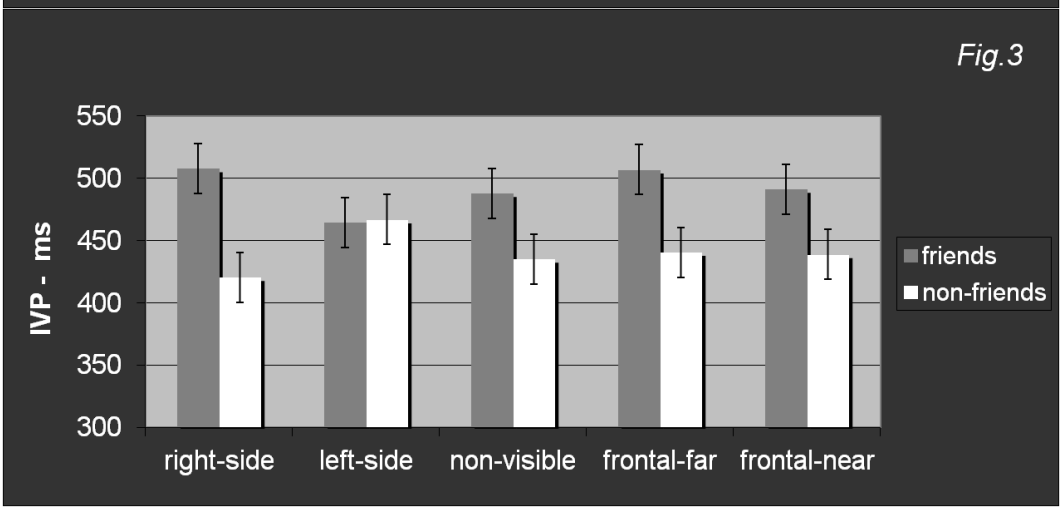


Fig.3
IVP - ms
550
500
450
400
350
300
right-side
left-side
non-visible
frontal-far
frontal-near
friends
non-friends

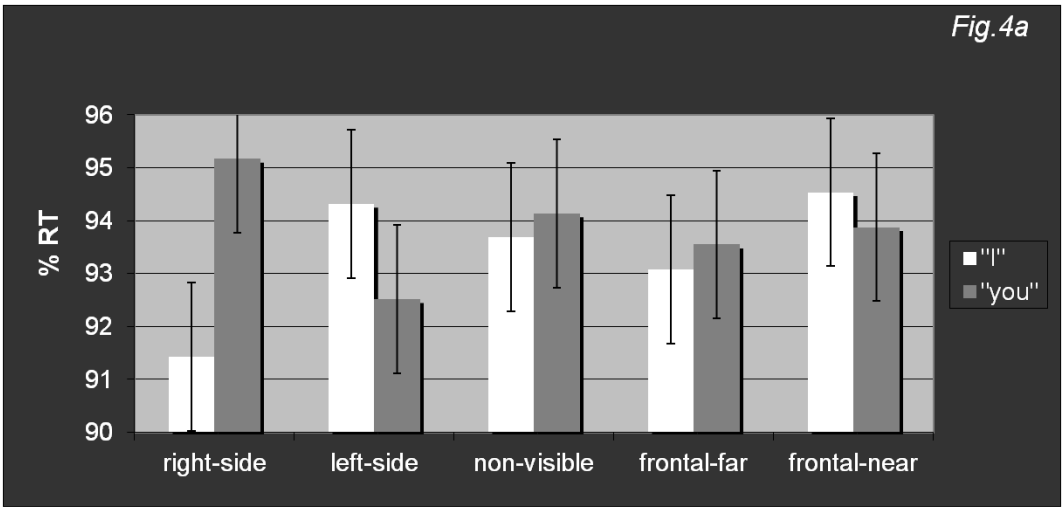


Fig.4a
% RT
96
95
94
93
92
91
90
right-side
left-side
non-visible
frontal-far
frontal-near
"I"
"you"

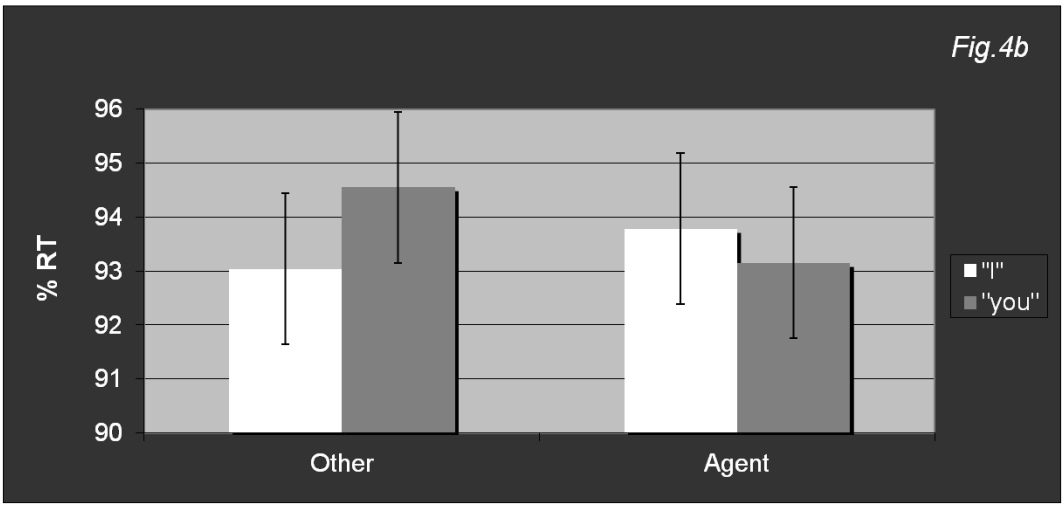


Fig.4b
% RT
96
95
94
93
92
91
90
Other
Agent
"I"
"you"