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Short Communication

Does the intention to communicate affect action kinematics?

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ABSTRACT

The aim of the present study was to investigate the effects of communicative intention on action. In Experiment 1 participants were requested to reach towards an object, grasp it, and either simply lift it (individual condition) or lift it with the intent to communicate a meaning to a partner (communicative condition). Movement kinematics were recorded using a three-dimensional motion analysis system. The results indicate that kinematics was sensitive to communicative intention. Although the to-be-grasped object remained the same, movements performed for the 'communicative' condition were characterized by a kinematic pattern which differed from those obtained for the 'individual' condition. These findings were confirmed in a subsequent experiment in which the communicative condition was compared to a control condition, in which the communicative exchange was prevented. Results are discussed in terms of cognitive pragmatics and current knowledge on how social behavior shapes action kinematics.

1. Introduction

In contrast to other species, for human beings the possibility of communication is not confined to a limited number of signals. Every action can, in principle, become a communicative signal. The only pre-requisite is that the action is intended as communicative by the actor and recognized as such by the partner (Bara, in press). For example, the action of touching one's earlobe – which is per se non-communicative – could become communicative in the context of a poker card game, when two players agree that touching the earlobe means: "Drop out the current hand". An unexplored question is whether the imposition of a communicative meaning to an action affects action kinematics, i.e. how the action itself is implemented at the motor level.

Hierarchical models of action representation (e.g., Hamilton & Grafton, 2007; Wohlschläger, Gattis, & Bekkering, 2003) postulate different levels of motor control, relatively independent from each other. Common to different approaches is the idea of a progressive refinement, from an intentional level, to an object-goal level and finally to a kinematic level, which represents the actions required to achieve the goal. Finally, at a muscle level, the selected action is specified through the coordinated activation of muscles.

Whereas much is known about the organization of the lower levels, including selection of kinematic parameters, only a few studies have attempted to examine higher levels of motor control (e.g., Grafton & Hamilton, 2007). For example, little is known about how kinematic parameters (kinematic level) are influenced by the organized set of intention that one may entertain (intentional level) when performing the same object-directed action.

In the present study, we examine this issue by focusing on communicative intention. In principle every action can become communicative, but the question is to understand whether imposing a communicative intent might influence the parame-

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terisation of the action kinematic. To answer this question we asked participants to perform the same goal-directed action in two different contexts that were operationalized through an individual task and a communicative task. In the individual task, participants were requested to reach towards, grasp and lift either a blue or a green spherical object according to one of five predetermined sequences. The communicative task was identical to the individual task except that participants executed the sequence with a communicative intent. Each of the sequences of blue and green spheres represented a different meaning in a sort of simplified Morse code. Participants were asked to select a meaning (and thus a sequence) and to communicate it to a partner by lifting the spheres in the predetermined order. Based on a conversion table, the partner had to interpret the meaning of the communicated sequence. Our interest was to ascertain whether the intention to communicate reflected on how the spheres were reached towards and grasped.

2. Experiment 1

2.1. Methods

2.1.1. Participants

Ten subjects (7 women and 3 men, mean age 24 years) participated in the experiment. All were right-handed, reported normal or corrected-to-normal vision and were naïve as to the purpose of the study.

2.1.2. Stimuli

Stimuli were two plastic spheres (diameter: 4 cm, weight: 5 g) one blue and one green positioned on a black table at a 30 cm distance from a hand starting location along the midsagittal plane.

2.1.3. Apparatus

The working surface was a rectangular table (150 × 100 cm). The participant was seated on a height adjustable chair. Before each trial, the right hand of each participant rested on a starting pad (brown velvet cloth 7 × 6 cm). The starting pad was attached 3 cm away from the edge of the table on the midsagittal axis 15 cm anterior to the subject's midline (see Fig. 1).

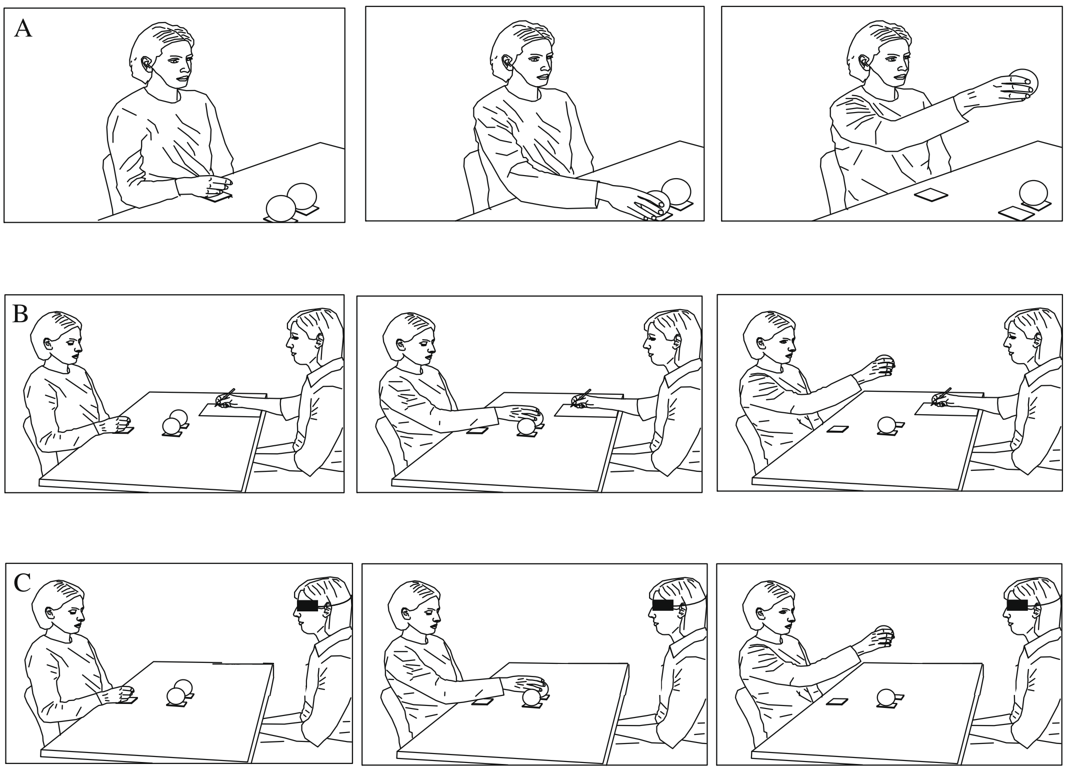

Fig. 1. Panel 'A' depicts the sequence of events for the 'individual' condition for Experiment 1. From left to right, the participant is resting her hand on a starting pad, then she reaches towards, grasps and lifts the object. Panel 'B' depicts the sequence of events for the 'communicative' condition applying to both Experiments 1 and 2. From left to right, the participant is resting her hand on a starting pad, then she reaches towards, grasps and lifts the object on the basis of the chosen color sequence as to communicate a specific word. Finally, the co-experimenter writes on a paper sheet the deciphered word. Panel 'C' depicts the sequence of events for the 'control' condition in Experiment 2. Please note that this condition is similar to the 'communicative' condition in Experiment 1 except that the co-experimenter was blindfolded.

Infrared reflective markers (0.25 mm diameter) were taped to the following points on the participants' right upper limb: (1) wrist – dorsodistal aspect of the radial styloid process; (2) thumb – ulnar side of the nail; and (3) index finger – radial side of the nail. Markers were fastened using double-sided tape. Movements were recorded using an ELITE motion analysis system (Bioengineering Technology & Systems [B|T|S]). Four infrared cameras (sampling rate 100 Hz) placed 120 cm away from each of the four corners of the table captured the movement of the markers in 3D space. Co-ordinates of the markers were reconstructed with an accuracy of 0.2 mm over the field of view. The standard deviation of the reconstruction error was 0.2 mm for the vertical (*Y*) axis and 0.3 mm for the two horizontal (*X* and *Z*) axes.

2.1.4. Procedure

Participants were presented with five different color sequences drawn on a paper sheet. They were instructed to choose four sequences and decide an order of sequence presentation. Each sequence was characterized by a specific color combination (e.g., blue, blue, green, green). The task was to reach, grasp and lift the spheres on the basis of the color order characterizing each sequence. Movement began as soon as a tone (880 Hz/200 ms) was presented. There were two experimental conditions administered to participants in a counterbalanced order:

1. *Individual condition*: In this condition, the participant, seated alone, was instructed to reach, grasp and lift the spheres in the order dictated by the sequences (see Fig. 1A).
2. *Communicative condition*: In this condition, two participants (a naïve subject and a co-experimenter) were seated opposite to each other (see Fig. 1B, first panel from the left). Both were given a conversion table in which each of the five sequences corresponded to a word. Participants were made to believe that the co-experimenter was just another naïve participant. The task for the participants was to reach towards, grasp and show to the co-experimenter one of the sequences by using the colored spheres as to allow her to decipher the word corresponding to the sequence (see Fig. 1B). Once the participant had completed the sequence, the co-experimenter did verbalize the communicated word. To avoid the possibility that the co-experimenter could guess the last word by exclusion, five different sequences were included.

2.1.5. Data processing

The ELIGRASP software package (B|T|S|) was used to analyze the data and provide a 3-D reconstruction of the marker positions as a function of time. The data were then filtered using a finite impulse response linear filter (transition band = 1 Hz, sharpening variable = 2, cut-off frequency = 10 Hz; D'Amico and Ferrigno, 1990, 1992). Following this operation, for the reaching component the spatial trajectory and tangential speed of the marker on the wrist were computed. For the grasp component the distance between the markers located on the index finger and the thumb was computed. Tangential speed data were used to determine the onset and offset of the movement using a standard algorithm (threshold for movement onset and offset was $\sim$5 mm/s).

In order to test our specific experimental hypothesis, we relied on dependent measures which, as previously demonstrated, show differences when comparing individual versus social attitudes (Becchio, Sartori, Bulgheroni, & Castiello, 2008a, 2008b; Georgiou, Becchio, Glover, & Castiello, 2007). For the reaching component these measures were the time of the maximum height of the wrist trajectory from the working surface and the amplitude of the maximum curvature of the trajectory path from an ideal line linking the starting position and the object location. In particular, we expected an anticipation of the maximum height and a more pronounced deviation of the wrist trajectory for the communicative than for the individual condition. For the grasping component we considered key kinematic parameters concerned with hand aperture – specifically, the time at which maximum hand aperture occurs and the pattern of fingers' opening/closing velocity. We predicted that an action planned on the basis of a communicative intent would determine a delay in the unfolding of the grasping component.

Altogether, this pattern of results would signify that the participant is planning an action more carefully when reaching towards and grasping an object with the intent to communicate to the partner.

2.1.6. Data analysis

Data analysis was confined to the reach-to-grasp phase, up to the point the object was contacted by the fingers. We adopted this strategy to investigate whether, prior to the act of lifting, the participant's intention to act individually versus communicatively shaped the kinematics of the action. A one-way analysis of variance (ANOVA) with experimental condition (individual, communicative) as a within-subjects factor was performed for each dependent measure. Preliminary analyzes revealed that the stimulus color (blue or green) resulted in no significant differences in kinematics. Therefore, data for 'blue' and 'green' stimuli have been collapsed.

2.2. Results and discussion

For the reaching component, the time of maximum trajectory height was reached earlier in communicative than individual conditions (461 vs. 504 ms; $F_{(1,9)} = 6.74$; $p < .05$; $\eta_p^2 = 0.47$; see Fig. 2A). In relative terms the maximum trajectory deviation was greater for the communicative than for the individual condition (54% vs. 48%; $F_{(1,9)} = 6.60$; $p < .05$; $\eta_p^2 = 0.43$; see

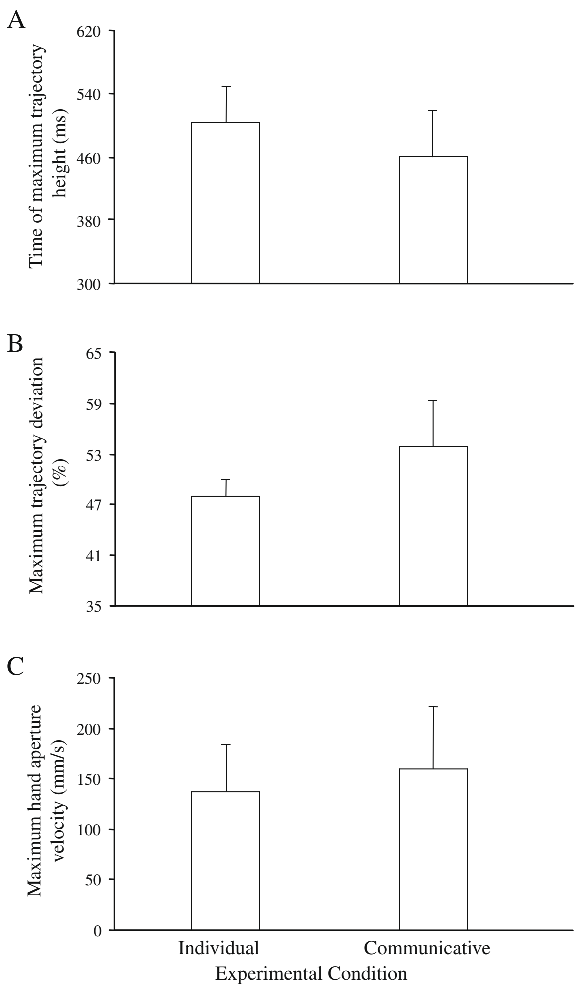

Fig. 2. Experiment 1. Graphical representation of the mean values for the 'individual' versus the 'communicative' conditions for the time of maximum trajectory height (panel 'A'), the maximum trajectory deviation as a percentage of movement duration (panel 'B') and the amplitude of maximum hand aperture velocity (panel 'C'). Bars represent standard deviation. mm/s = millimeters by seconds; ms = milliseconds; % = percentage.

Fig. 2B). For the grasping component, participants opened the hand as to reach maximum hand aperture faster for the communicative than for the individual condition (160 vs. 137 mm/s; $F_{(1,9)} = 5.98$; $p < .05$; $\eta_p^2 = 0.44$; see Fig. 2C).

What the present results reveal is that the imposition of a communicative intent is not neutral with respect to action kinematics: the intention to communicate alters the parameterisation of the movement. Therefore, the very same action – reaching towards and grasping a sphere – is executed differently depending on whether it carries a communicative or a purely individual intent. Along these lines, a higher speed of finger opening for the 'communication' condition may signify that when the task was to use the object as to communicate to another person, participants needed more time during the 'closing' phase to compute a careful approach to the object. This is because the placement of fingers on an object changes with respect to the accuracy requirements of action end-goals (e.g., Ansuini, Santello, Massaccesi, & Castiello, 2006). Therefore, when the lifting action is done to show the object to another person, then a more careful determination of contact points for the fingers might be desired to optimize the viewing of the object by the partner. In contrast, when the task is executed with a purely individual intention, the object can be grasped in whatever orientation without compromising the goal of the action. Similarly, anticipating the time at which the wrist trajectory reaches its peak and performing a more curved trajectory path allows for more time to prepare a suitable hand posture during a longer deceleration phase for the 'communication' condition.

3. Experiment 2

A possible objection against the interpretation given to the data obtained in Experiment 1 is that the presence of another person might be, per se, responsible for the differential pattern of results observed during the communicative condition. In other words, it could be argued that determining a different kinematic pattern is not the communicative intent underlying the action, but the mere presence of the co-experimenter. To exclude this alternative hypothesis in the present experiment we compared the communicative condition with a control condition in which participants acted in the presence of another person. The only difference between the communicative and the control condition was that in the latter condition the gaze of the co-experimenter was covered by a mask. Therefore no communicative exchange could occur between the participant and the co-experimenter.

3.1. Methods

3.1.1. Participants

Twelve participants (6 women and 6 men, mean age 23 years) with the same characteristics as those participating in Experiment 1 took part in the experiment. None of them participated in Experiment 1.

3.1.2. Stimuli, apparatus, and procedures

These were exactly the same as those for Experiment 1, except that participants were administered the following experimental conditions in a counterbalanced order:

1. *Control condition*: In this condition, two participants (a naïve subject and a co-experimenter) were seated opposite to each other. As for the communicative condition in Experiment 1, the task for the participants was to perform one of the color sequences corresponding to a word. However, differently from the communicative condition in Experiment 1, the eyes of the co-experimenter were covered by a mask (see Fig. 1C).
2. *Communicative condition*: This condition was identical to the communicative condition administered in Experiment 1 (see Fig. 1B).

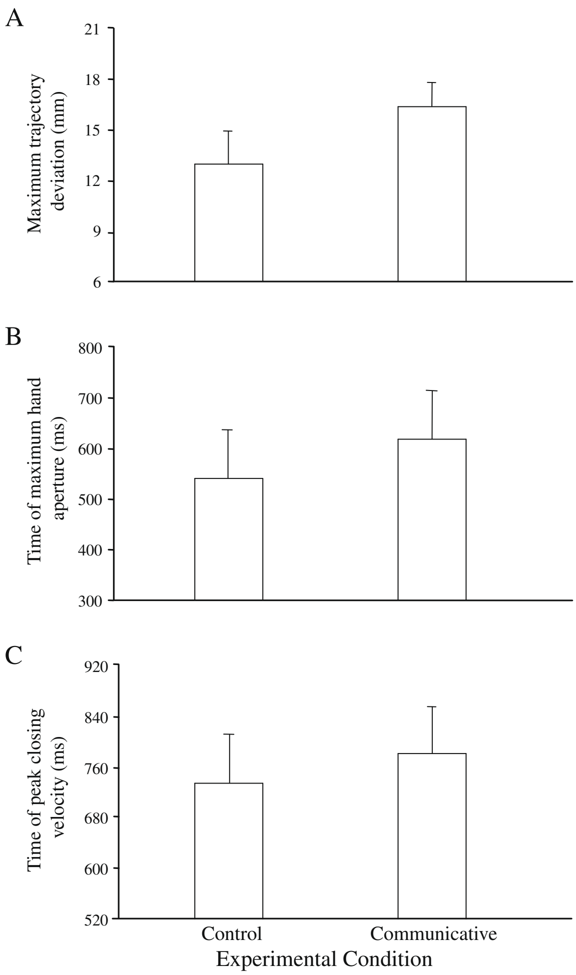

Fig. 3. Experiment 2. Graphical representation of the mean values for the 'control' versus the 'communicative' conditions for the maximum trajectory deviation (panel 'A'), the time of maximum hand aperture (panel 'B') and the time of peak closing velocity (panel 'C'). Bars represent standard deviation. mm/s = millimeters by seconds; ms = milliseconds; % = percentage.

3.1.3. Data processing and data analysis

These were identical to those described in Experiment 1.

3.2. Results and discussion

The analyses revealed that for the reaching component the maximum trajectory deviation was greater for the communicative than for the control condition (16 vs. 13 mm; $F_{(1,11)} = 5.78$; $p < .05$; $\eta_p^2 = 0.35$; see Fig. 3A). For the grasp component the time of maximum hand aperture (627 vs. 581 ms; $F_{(1,11)} = 7.05$; $p < .05$; $\eta_p^2 = 0.39$) and the time at which peak fingers closing velocity (806 vs. 746 ms; $F_{(1,11)} = 7.21$; $p < .05$; $\eta_p^2 = 0.40$) was reached were later for the communicative than for the control condition (see Fig. 3B and C).

Altogether this pattern of results mirrors that obtained for Experiment 1. That is, there was a tendency to plan a more careful approach to the object when the action was intended to be recognized by the partner. When the eyes of the partner were not available and the communicative exchange was prevented, then the kinematic features of the action resembled those obtained for the 'individual' condition in Experiment 1. It might be said that preventing the access to the gaze of the partner might bring to an artificial condition because it removes an indispensable channel of communication in the given scenario. However, our aim was to specifically control for the mere presence of another person excluding any communicative exchange. Because another person was present in both the communicative and the control condition, the possibility that differences in kinematic patterns between the two conditions simply reflect the presence/absence of another agent can be ruled out.

4. General discussion

We set out to investigate whether the imposition of a communicative intent on an action might influence the action kinematic parameterization. Previous studies have already shown that intention mechanisms modulate actions kinematics (Ansuini et al., 2006; Becchio et al., 2008b; Castiello, 2003). For example, kinematics has been shown to be sensitive to prior intentions, i.e. intentions formed in advance and representing the end-goal of the action (Searle, 1983). Ansuini et al. (2006) found that modulation of hand shape during reach-to-grasp takes into account the end-goal of the action in addition to object geometry. Specifically, hand shaping is different depending on whether the prior intention is to lift the object or to insert it into a niche. Becchio et al. (2008b) demonstrated similar effects for social intentions, i.e. intentions directed towards another person. In this study, participants were requested to move an object from a location to another (individual intention condition) or to pass it to a partner (social intention condition). Different kinematics patterns were observed for "moving" actions and "passing" actions.

The present study extends our knowledge of intentional mechanism to a different and yet unexplored form of intentionality, i.e. communicative intentionality. In a pragmatic approach, communicative intentions can be regarded as a special form of social intentions (Bara, in press). What renders communicative intentions special is that they not only are directed towards another agent, but also require, as part of their content, that the other agent recognizes the speaker's intention to communicate (Grice, 1989). So conceived, communicative intentions (a) always occur in the context of a social interaction with a partner, (b) are overt, in the sense that they are intended to be recognized by the partner and (c) their satisfaction consists precisely in the fact that they are recognized by the partner.

By implementing these three requirements, the present experiment provides the first measure of the influence that communicative intentions exert on the level of action kinematics. In particular, key kinematic parameters were found to be different for the communicative condition compared to the individual condition. The modification observed in these parameters fits well with the idea that communicative actions are planned as a function of the partner's recognition (Grice, 1989). Further strength to this hypothesis comes from the results obtained for Experiment 2 in which a control condition implying the presence of a blindfolded agent was used. This manipulation proved to be sufficient as to eliminate the 'communicative' effect.

It is worth nothing that neither intra-personal nor inter-personal motor constraints account for the present results. First, because the subsequent action was the same for both the communicative and the individual condition (lift the object), this rules out the possibility that differences in kinematics simply reflect differences in motor planning. Whereas such explanation may account for actions executed with different prior intention and thus followed by different actions (e.g., Ansuini et al., 2006), it does not apply to actions motivated by different intentions (communicative vs. individual), but followed by the same lifting action. Second and more importantly, because the object was held by the agent and simply showed to the partner in the communicative condition, this eliminates the possibility that differences in kinematics reflect mere inter-personal coordination constraints. Indeed, whereas passing an object requires adjusting one's action to the action of another individual (Becchio et al., 2008a; Meulenbroek, Bosga, Hulstijn, & Miedl, 2007), communicating a meaning does not require any motor coordination with others. What is required is simply that the other person recognizes the communicative signal generated by the agent and attributes the correct meaning to it.

In conclusion, our results support the view that specific kinematic patterns characterize and distinguish communicative actions from actions executed with a purely individual intent. In line with a pragmatic approach to communication, we interpret this finding as evidence that communicative actions are intended to be recognized by a partner. Whether the partner makes use of kinematic cues in order to distinguish communicative from non-communicative actions is an interesting topic for further research.

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