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Identifying others' informative intentions from movement kinematics

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ABSTRACT

Previous research has demonstrated that people can reliably distinguish between actions with different instrumental intentions on the basis of the kinematic signatures of these actions (Cavallo, Koul, Ansuini, Capozzi, & Becchio, 2016). It has also been demonstrated that different informative intentions result in distinct action kinematics (McEllin, Knoblich, & Sebanz, 2017). However, it is unknown whether people can discriminate between instrumental actions and actions performed with an informative intention, and between actions performed with different informative intentions, on the basis of kinematic cues produced in these actions. We addressed these questions using a visual discrimination paradigm in which participants were presented with point light animations of an actor playing a virtual xylophone. We systematically manipulated and amplified kinematic parameters that have been shown to reflect different informative intentions. We found that participants reliably used both spatial and temporal cues in order to discriminate between instrumental actions and actions performed with an informative intention, and between actions performed with different informative intentions. Our findings indicate that the informative cues produced in joint action and teaching go beyond serving a general informative purpose and can be used to infer specific informative intentions.

1. Introduction

People derive mental states such as intentions and expectations from observing the movements of others (Cavallo, Koul, Ansuini, Capozzi, & Becchio, 2016; Grèzes, Frith & Passingham, 2004). Using early movement kinematics of perceived actions, observers can discriminate between different instrumental intentions (Cavallo et al., 2016; Manera, Becchio, Cavallo, Sartori, & Castiello, 2011). In addition, informative intentions can also be reflected in kinematics. On the one hand, people acting together produce informative action modulations in order to support interpersonal coordination by facilitating spatial and temporal prediction (Pezzulo, Donnarumma & Dindo, 2013; Vesper & Richardson, 2014; Vesper, Schmitz, Safra, Sebanz, & Knoblich, 2016). On the other hand, parents and teachers modify their movements to support learning through demonstration by highlighting the structure of an action (Brand, Baldwin & Ashburn, 2002). These findings suggest that the same action can be modulated in different ways to convey different informative intentions to an observer.

But can observers actually identify informative intentions based on movement kinematics? The first aim of the present study was to investigate whether people can discriminate actions with informative intentions from actions without informative intentions using kinematic cues. The second aim was to investigate whether people are able to distinguish different interactive intentions based on kinematic cues. Specifically, we asked whether observers can tell whether perceived agents are intending to teach a co-actor or whether they intend to perform a coordinated joint action with a co-actor.

1.1. Perceiving intentions from actions

Much of the research on perception of individuals' intentions has focused on perception of instrumental actions. This research has demonstrated that humans have the ability to derive different mental states of an actor by observing the kinematics of their actions. For instance, people can recognize whether an actor intends to cooperate or compete (Manera et al., 2011), whether or not an actor has a false belief (Grèzes, et al., 2004) or even whether or not an actor has a deceptive intention (Runeson & Frykholm, 1983). Even though these actions are not intended to inform, people can still read mental states from them.

A recent study by Cavallo et al. (2016) demonstrated that people can discriminate observed actors' instrumental intentions based on early kinematic features of the action. In their study participants observed reach to grasp movements of actors intending to grasp a bottle in order to pour from it, or in order to drink. They found that kinematic features such as wrist height and grip aperture predicted how well an observer could discriminate between the two different underlying

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intentions. Moreover, the accuracy of participants' discrimination between the two underlying intentions could be modulated by modifying kinematic parameters that predicted classification accuracy. In contrast to many earlier studies, Cavallo et al. (2016) were not only able to show that different intentions can be discriminated, but they could also quantify the contribution of different kinematic parameters to the accuracy of identifying a particular intention.

There is also evidence that movement kinematics carry information about social intentions. Becchio, Sartori, Bulgheroni and Castiello (2008) carried out a study in which participants were required to grasp an object to build a tower together with a co-actor, either with a cooperative intention (build the tower together) or a competitive intention (place the object at the bottom of the tower before the other participant). They showed that compared to competitive actions, cooperative actions had a larger trajectory, were slower, and displayed a smaller grip aperture. Another study by Manera et al. (2011) demonstrated that people could discriminate between cooperative and competitive intentions when perceiving reach to grasp movements. Moreover, participants could still discriminate between competitive and cooperative intentions when viewing point light displays of reach to grasp movements, demonstrating that dynamic kinematic cues were used to discriminate between different intentions.

Evidence obtained in sports experts indicates that identifying intentions from action kinematics taps into motor simulation. Aglioti, Cesari, Romani and Urgesi (2008) demonstrated that expert basketball players could predict the accuracy of a free throw on the basis of the player's kinematics, whereas expert watchers and novices could not. Similarly, Sebanz and Shiffrar (2009) found that expert basketball players could distinguish real passes from fake passes by observing another player's actions, both when the actions were shown in videos and when they were shown as point-light displays. In contrast, novice basketballers were not able to discriminate real and fake passes. These results imply that motor expertise can be a pre-condition for identifying intentions from an observed agent's kinematics.

In sum, previous research shows that movement kinematics provide a rich source of information that observers can use to make predictions about observed agents' intentions. Even when instrumental actions are not intended to inform the observer, they are nonetheless a rich source of information due to dedicated perceptual processing of kinematic cues (Becchio, Cavallo, Begliomini, Sartori, Feltrin, Castiello et al., 2012; Becchio, Manera, Sartori, Cavallo, Castiello, 2012) and people's ability to map observed actions onto their own motor repertoire (Ansuini, Cavallo, Bertone & Becchio, 2015; Rizzolatti and Sinigaglia, 2010).

1.2. Sensorimotor communication in joint action coordination and teaching

The kinematics of an action do not only provide cues to intention as a side effect of an actor's performance, but they can also reflect an actor's intention to inform another agent (Sperber & Wilson, 2004). Thus, action kinematics can be actively used as a channel of information for joint action coordination and communication. Pezzulo et al. (2013) coined the term 'sensorimotor communication' for this active use of kinematics to inform. Sensorimotor communication is special compared to other forms of communication in that communication is superimposed on performed instrumental actions. Specifically, actors make instrumental actions informative by modulating kinematic parameters so that the actions become more predictable and less ambiguous (Pezzulo, et al., 2013).

Sensorimotor communication is often observed in joint actions, where co-actors make their actions more informative in order to effectively achieve interpersonal coordination. In a study by Sacheli, Tidoni, Pavone, Aglioti, and Candidi (2013), two participants were instructed to grasp a bottle synchronously with either a power or a precision grip. Crucially, only the 'leader' knew which part of the bottle to grasp, while the 'follower' relied on the leader's actions to select the appropriate grip. Compared to followers, leaders reduced the velocity of their movements, and modulated wrist height and grip aperture. This made their movements more informative, communicating task relevant information to their joint action partner. It is also important to note that sensorimotor communication is only produced when informative cues are required, which is evidenced by findings demonstrating that actors no longer produce kinematic cues when their co-actor already has access to the information necessary to complete the joint task (Pezzulo & Dindo, 2011; Leibfried, Grau-Moya, & Braun, 2015).

Developmental research on imitation shows that sensorimotor communication also occurs in teaching contexts, with teachers adjusting their actions to make them more informative for the learner. Brand, et al. (2002) found that when mothers demonstrated actions to their children, their movements were more punctuated and pronounced, with a larger range of motion. This was labelled 'motionese' and has been shown to facilitate imitation of observed actions. Infants are more likely to imitate actions containing motionese, compared to actions without motionese (Koterba & Iverson, 2009). It has been proposed that motionese enhances understanding of the goal structure of the action by guiding attention to important parts of an action sequence (Nagai and Rohlfing, 2009). These studies can be taken as evidence that sensorimotor communication is important for teaching through demonstration.

Using a virtual xylophone playing task, McEllin, Knoblich and Sebanz (2017) directly compared sensorimotor communication in joint action and in teaching through demonstration. Participants who had been trained to play melodies on a virtual xylophone produced different kinematic cues when trying to play the melodies in synchrony with a novice, compared to when they were demonstrating melodies to a novice. Specifically, modulations of movement height were used to support both teaching and coordination, modulations of the acceleration phase (ascent) of a movement were used to support spatial prediction in joint action coordination, and modulations of the deceleration phase (descent) of a movement were used to support temporal prediction in joint action coordination. This indicates that different kinematic cues are produced to support different informative intentions. In joint action kinematic cues are optimized to make the communicator's action more predictable, whereas in teaching kinematic cues are optimized to orient the learner's attention.

1.3. Reading informative intentions from actions

The finding that communicators modulate the kinematics of their actions differentially in joint action and teaching contexts raises the question of whether the recipients of the communication can identify communicators' informative intentions from observing their movements. We first aimed to investigate whether the recipients of sensorimotor communication can distinguish instrumental actions that have an informative intention superimposed from regular instrumental actions. Given that actors differentially modulate kinematics for different informative intentions (coordination vs teaching), we further aimed to investigate whether people can distinguish different informative intentions based on the kinematics of observed actions. Finally, we aimed to investigate which types of kinematic cues make people perceive that an actor has a coordination intention or a teaching intention.

We used a task in which participants were presented with a point light-display of a mallet movement that corresponded to an actor playing simple melodies on a virtual xylophone. Participants were asked to categorize the displays as reflecting individual action, demonstration for teaching, or part of a coordinated joint action. The observed movements were synthesized so that they corresponded to fundamental movement laws. Maximum height and velocity profile of the movements were systematically varied because they had been identified as the main cues communicators used in coordination and teaching contexts in our previous study (McEllin et al., 2017). Artificially modulating kinematic parameters rather than using natural kinematics gave us full experimental control over the kinematic cues in