Human Movement Science 54 (2017) 197–209

Contents lists available at ScienceDirect

Human Movement Science

journal homepage: www.elsevier.com/locate/humov

Full Length Article

# Index of difficulty and side of space are accommodated during the selection and planning of a joint action

Matthew Ray*, John de Grosbois, Timothy N. Welsh

*Faculty of Kinesiology and Physical Education, University of Toronto, 55 Harbord St, Toronto, ON M5S 2W6, Canada*

ARTICLE INFO

*Keywords:*
Sequential joint action
Shared task representation
Common coding
Motor experience
Action anticipation
Response features

ABSTRACT

Co-actors can facilitate the achievement of a shared goal by accurately anticipating each other's needs and subsequently planning actions to accommodate those needs. The purpose of the present study was to determine if co-actors plan and execute their movements to accommodate the difficulty of their partners' action. We hypothesized that information derived from shared task representations could influence the simulation of other's actions and that motor experience would enhance the ability of co-actor's to anticipate their co-actor's needs. Partners performed a sequential aiming task. The *initiator* of the sequential action placed a dowel on a line between two potential targets that varied in size across trials. The *initiator* did not know the actual target location prior to placing the dowel. The *finisher* then grasped the dowel and moved it to whichever target was signaled, from wherever their partner had placed the dowel. Participants completed the partner task before and after completing an individual task in which they completed both the initiating and the finishing movements. Consistent with the prediction that co-actors represent the difficulty of their partners' actions, the dowel was placed closer to the smaller target of a pair. Further, it was found that motor experience influenced dowel placement – there was a shift in dowel placement following the completion of the individual task. These results indicate that co-actors plan their movements based on features of their co-actor's movements and that motor experience provides information that allows people to better plan movements for their partners.

## 1. Introduction

When humans work together, they have the ability to achieve goals that could not be accomplished when working alone. Indeed, humans engage in social behaviours to a larger degree than other mammals and cooperation among humans has been proposed to be one of the evolutionary advantages that humans have over other nonhuman animals (Boyd & Richerson, 2009). For example, humans can transmit information to each other via verbal and non-verbal communication, plan the actions of multiple people to build massive structures that could not be built alone, coordinate the actions of a group to hunt larger animals, empathize and understand each other's mental states, and teach skilled behaviours. When humans come together in space and time to achieve a shared goal, they are performing "joint actions" (Sebanz, Bekkering, & Knoblich, 2006). Due to the central role that joint actions play in human life, a better understanding of human social behaviour as a whole can be developed through the investigation of the cognitive and motor processes that underlie joint actions.

One cognitive process that could contribute to the achievement of a shared goal is the accurate anticipation of the specific features

* Corresponding author at: Ocean Safety Research, Marine Institute, Memorial University, 155 Ridge Rd, St. John's NL A1B 5E7, Canada.
*E-mail address:* Matthew.Ray@mi.mun.ca (M. Ray).

http://dx.doi.org/10.1016/j.humov.2017.05.009
Received 22 February 2017; Received in revised form 5 May 2017; Accepted 14 May 2017
Available online 17 May 2017

of a co-actor's future action. When an individual has accurately anticipated what their co-actor will do, then that individual could plan an action that facilitates their co-actor's action. For example, an expert carpenter, who is perched on a ladder, could work faster if there is an assistant who is capable of accurately anticipating both what tool they need and how they will use it. For example, a hammer could be passed with the handle towards the carpenter rather than the head if the carpenter is going to use it right away. In contrast, if the assistant is unable to accurately anticipate how the tool will be used, then the carpenter might have to make compensatory adjustments, which would slow down the task. Such facilitatory response planning in joint action contexts has been observed in the lab (Gonzalez, Studenka, Glazebrook, & Lyons, 2011; Ray & Welsh, 2011); however, questions still remain as to what details of a co-actor's task are represented and what features of a co-actor's action can be anticipated and integrated into the response planning of a joint action. The purpose of the present study was to investigate if individuals anticipate and accommodate the needs of their co-actor during the selection and planning of a joint action and how experience might shape that process.

### *1.1. Shared task representations and motor simulation*

Although there are many processes that are required to facilitate joint actions, there are two cognitive processes that have been posited to contribute to an individual's ability to accurately anticipate their co-actor's action: 1) the development and use of shared task representations (Pezzulo, 2011; Sebanz & Knoblich, 2009; Vesper, Butterfill, Knoblich, & Sebanz, 2010), and 2) the ability to represent and simulate a co-actor's action, in an individual's own motor system, during the perception, imagination or anticipation of their co-actor's action (Sebanz & Knoblich, 2009; van der Wel, Sebanz, & Knoblich, 2013; Vesper, Knoblich, & Sebanz, 2014). The shared task representation has been suggested to contain the shared goal, knowledge pertaining to each co-actor's task (including the actions required to complete the shared goal), and contextual knowledge and beliefs (Pezzulo, 2011; Vesper et al., 2010). To accurately anticipate the outcome of another person's action, the information contained in the shared task representation is hypothesized to inform the predictive simulation of another's action in one's own motor system (Sebanz & Knoblich, 2009). Therefore, the content of a shared task representation can affect what is actually predicted during the action simulation.

Based on these two cognitive processes (representing another's task and simulating another's action), there are at least two potential factors that could impact how accurately co-actors anticipate each other's actions. First, because actions can be represented at multiple levels (Jeannerod, 1994; Pacherie, 2008; Pezzulo, 2011), individuals may represent their co-actor's actions at a more global or higher goal-oriented level as opposed to a fully specified functional/kinematic level. For example, Pacherie's (2008) framework holds that, based on the state of the individual, the goal, and the environment, motor representations can range from overarching goals and beliefs that are not yet specified, to fully parameterized actions (i.e., response features are known). For the purpose of the present paper, response "features" are meant to describe how the action could be carried out, such as movement direction, amplitude and speed/movement time (i.e., pragmatic content; Jeannerod, 1994). In a joint action context, if an individual represented their co-actor's goal (e.g., transport object to target), task features (e.g., small target) and movement related features (short, fast movement to the left), then an action simulation based on that information would yield an accurate prediction of their co-actor's potential movement outcome. In contrast, if an individual only represented the overarching goal (transport object to target) but not the task or movement features, then it would be difficult to accurately anticipate how they will achieve their goal.

The second factor that could influence how accurately individuals anticipate their co-actor's action is that even if an individual represents their co-actor's action as a fully parameterized action, the motor representation being simulated might still be lacking in detail. Jeannerod (2003) has pointed out that when individuals represent other people's actions in their own motor system, they will not have access to higher level intentions and goals as well as the actual sensory input associated with the action of the other person. In a joint action context, if an individual represented their co-actor's action in similar way that they represented their own, then the outcome of the simulated action should be more detailed. This representation might still be limited, however, due to individual differences in motor experience and motor function and the lack of actual sensory information from the anticipated movement.

The common coding theory of perception and action (Hommel, Musseler, Aschersleben, & Prinz, 2001; Prinz, 1997) is one theoretical framework that can be used to help explain what action features might be represented during the anticipation of a co-actor's action (Eskenazi, van der Wel, & Sebanz, 2012; Sebanz & Knoblich, 2009; van der Wel et al., 2013). Common coding accounts of perception and action posit that the perception, imagination and preparation of actions are enabled by a system in which the neural codes representing actions and the perceptual effects of those actions are tightly bound in a common representational format (Hommel et al., 2001; Prinz, 1997). Due to this tight binding, there is a bidirectional relationship between perception and action such that the perception of an action activates motor codes that are bound to the perceptual codes, and the preparation of an action activates perceptual codes that are bound to the motor codes (Hommel et al., 2001; Prinz, 1997). Therefore, one factor that might influence what action features are represented during the anticipation of a co-actor's action, is the current binding between perceptual and motor codes (for a review of the binding between perception and action codes see: Hommel & Elsner, 2009).

If the level of detail that an individual represents their co-actor's action is based on the current state of binding between perceptual and motor codes within the individual (i.e., how the individual would perform the task themselves), then an individual's personal action history could influence what action features are anticipated and integrated into the response planning of a joint action. Indeed, there is some evidence in support of the hypothesis that a person's action history might influence the representation of another's action. For example, the magnitude of the neural responses in the action observation system seems to be dependent on one's personal action history (e.g., Calvo-Merino, Glaser, Grezes, Passingham, & Haggard, 2005), with larger magnitude responses emerging in individuals with greater levels of motor experience. Further, previous research has demonstrated that individuals are better at predicting (Knoblich & Flach, 2001) and coordinating actions with themselves (Keller, Knoblich, & Repp, 2007) than with others. However, at this point it is unclear if personal action history, and the potential differences in the motor representations for