



Interpersonal motor coordination during joint actions in children with and without autism spectrum disorder: The role of motor information



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ABSTRACT

Background: Kinematics plays a key role in action prediction, imitation and joint action coordination. Despite people with autism spectrum disorder (ASD) show a failure to use kinematic cues during observation and imitation, there is a paucity of studies exploring the role of this dysfunction during joint actions in children with ASD.

Aim: To evaluate the interpersonal motor coordination of children with ASD and typically developing (TD) children during a joint action task.

Method: Twenty-two participants performed two cooperative tasks. In the first one (Clear End-Point), children were provided with *a priori* information on movement end-point. In the second one (Unclear End-Point), the end-point was unknown and children had to use kinematic cues to accomplish the shared goal.

Results: We found no between-group differences in the first task, even if children with ASD displayed greater reaction time variability. In the second task, they showed less accurate and slower movements than TD children. Moreover, their movement features did not differ between the two tasks, whereas TD children showed reduced reaction time variability and number of errors in the second task.

Conclusion: Children with ASD were impaired in joint action coordination when they had to rely only on kinematic information. They were not able to pay more attention to the kinematic cues in absence of a visual goal.

What this paper adds

- Differently from TD children, children with ASD display reduced interpersonal motor coordination in absence of *a priori* information about the spatial features of other's movement. The predictive complexity of a joint action task affects, indeed, the synchrony and accuracy of their movements.
- A motor perspective on social impairment in children with ASD and the adoption of experimental paradigms investigating movement in “real-time” social interactions could promote new intervention strategies, i.e. “joint action” training, aimed at improving those motor interactions that may foster the development of social skills.

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1. Introduction

In addition to the core symptoms, namely the social communication impairment and restricted-repetitive behaviours (APA, 2013), children with Autism Spectrum Disorder (ASD) show a reduced ability to use motor information to predict the goal of observed actions (Boria et al., 2009). They show an even greater difficulty in imitating the meaningless or goal-less actions that require kinematic information (Cossu et al., 2012; Wild, Poliakoff, Jerrison, & Gowen, 2012). Conversely, there is some evidence of intact goal-directed imitation in children with ASD (Beadle-Brown & Whiten, 2004; Hamilton, Brindley, & Frith, 2007). A failure to use kinematic cues to imitate and predict the other's actions has been suggested as a key sensorimotor problem in people with ASD (Gowen, 2012). Moreover, research on motor control reported various sensorimotor deficits in children with ASD, including delay in movement initiation (Forti et al., 2011; Glazebrook, Elliott, & Szatmari, 2008; Glazebrook, Gonzalez, Hansen, & Elliott, 2009; Rinehart et al., 2006), longer movement duration (Glazebrook, Elliott, & Lyons, 2006; Stoit, van Schie, Slaats-Willemse, & Buitelaar, 2013), poor visuo-motor integration (Mayes & Calhoun, 2007) and difficulties in feed-forward processes during movement execution (David et al., 2009). Such motor abnormalities may contribute to social impairment by compromising the ability to adequately coordinate with others during interactions. These deficits emerge early in development, and have been reported in several studies involving children with variable severity of core behavioural symptoms as well as different levels of cognitive functioning (Fournier, Hass, Naik, Lodha, & Cauraugh, 2010; Hannant, Cassidy, Tavassoli, & Mann, 2016; Radonovich, Fournier, & Hass, 2013). However, literature data are extremely conflicting and the actual relationship between motor deficits and clinical features in children with ASD remains controversial (Fulceri et al., 2015; Green et al., 2009; Mari, Castiello, Marks, Marraffa, & Prior, 2003).

Several studies emphasized the hierarchical value of movement kinematics and action goals during the imitation of goal-directed and goal-less movements (Bekkering, Wohlschlagel, & Gattis, 2000; Carpenter, Call, & Tomasello, 2005; Wild, Poliakoff, Jerrison, & Gowen, 2010). If an action has a visual goal, it is given more importance than the movement. In absence of a visual goal, the kinematic features of the movement, such as its amplitude, speed, or trajectory, became more important. The dual-route action processing framework (Rumiati & Tessari, 2002) proposes that two different mechanisms subserve imitation: a direct visuomotor route for novel, goal-less movements and a semantic indirect route for meaningful and goal-directed movements. However, social context also plays a crucial role in influencing what exactly children give attention and copy (Over & Carpenter, 2012). It has been hypothesized that people with ASD could have a specific dysfunction in the direct visuomotor route (Hamilton, 2008).

Observing kinematics helps us to understand the actions of others (Stapel, Hunnius, & Bekkering, 2012). Moreover, kinematics guides the co-actors in predicting the temporal and spatial aspects of the joint actions to coordinate accurately with each other. However, there is lack of research exploring whether children with ASD fail to use kinematic information also during joint actions.

Joint actions are defined as “any form of social interaction whereby two or more individuals coordinate their actions in space and time to bring about a change in the environment” (Sebanz, Bekkering, & Knoblich, 2006). During a joint action, a planned co-ordination occurs when individuals plan their own actions in relation to the other's action to accomplish a shared goal (Knoblich & Sebanz, 2008). The ability to smoothly coordinate actions with others gradually develops during childhood, from early imitative interactions that play a crucial role in social development to more complex joint actions (Carpenter, Uebel, & Tomasello, 2013; Meltzoff & Moore, 1992; Meyer, Bekkering, Paulus, & Hunnius, 2010). When two or more individuals are involved in joint actions, complementary rather than imitative actions occur (Sartori, Bucchioni, & Castiello, 2013). Differently from the imitative ones, the complementary actions require the ability to select a motor act that complements the other's action to achieve joint goals. However, both imitation and joint actions are selective goal-directed processes requiring the ability to infer the action's goal (Sebanz et al., 2006). From the age of five years, children are able to adjust flexibly their movements to those of a partner by integrating the partner's constraints in their action plan (Meyer, Bekkering, Haartsen, Stapel, & Hunnius, 2015).

Both sensorimotor and cognitive processes are needed for interacting and coordinating actions with others in space and time. These include the ability to share a common goal (i.e., “what”), to engage in joint attention (i.e., “where”) and to predict the timing of other's actions and plan own actions in order to achieve a temporal coordination (i.e., “when”) (Sebanz & Knoblich, 2009). Successful prediction in joint actions relies on *a priori* knowledge about the action's goal and on the movement's kinematic features (Cuijpers, van Schie, Koppen, Erlhagen, & Bekkering, 2006; Kilner, Friston, & Frith, 2007).

To date, only few studies have investigated joint action coordination in children with ASD. Some studies reported that individuals with ASD coordinate their actions with others to share a common goal (Fitzpatrick, Diorio, Richardson, & Schmidt, 2013; Gonzalez, Glazebrook, Studenka, & Lyons, 2013), and that they can understand the goal of others and help them to achieve it (Liebal, Colombi, Rogers, Warneken, & Tomasello, 2008). However, impairments emerge when the task difficulty increases (Dowd, McGinley, Taffe, & Rinehart, 2012; Glazebrook et al., 2008). People with ASD seem to be particularly impaired in planning their movements while taking into account the other's motor plan (Gonzalez et al., 2013; Scharoun & Bryden, 2016). Moreover, they perform more poorly in cooperative tasks than children with developmental delay (Colombi et al., 2009; Jahr, Eldevik, & Eikeseth, 2000; Liebal et al., 2008) and this deficit seem to be linked to impairments in imitation and joint attention (Colombi et al., 2009).

The main aim of this study was to investigate the ability of children with ASD to coordinate own manual actions with those of another person, during a joint action task. We analysed the kinematic and behavioural features of reaching movements in children with ASD compared to typically developing (TD) children, in two different conditions. In the first condition, children were provided with clear information about the goal and the intended end-point of the examiner's movements. In the second condition, the end-point was unknown and children had to predict it and adjust their movements accordingly by relying on perceptive information about the examiner's movement. Additionally, we investigated the relationship between the clinical features of children with ASD and their joint action coordination ability.

Based on the aforementioned studies in children with ASD reporting a failure in using kinematic cues to predict the other's action

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