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One hand, two hands, two people: Prospective sensorimotor control in children with autism

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ABSTRACT

Where grasps are made reveals how grasps are planned. The grasp height effect predicts that, when people take hold of an object to move it to a new position, the grasp height on the object is inversely related to the height of the target position. In the present study, we used this effect as a window into the prospective sensorimotor control of children with autism spectrum disorders without accompanying intellectual impairment. Participants were instructed to grasp a vertical cylinder and move it from a table (home position) to a shelf of varying height (target position). Depending on the conditions, they performed the task using only one hand (unimanual), two hands (bimanual), or with the help of a co-actor (joint). Comparison between the performance of typically developing children and children with autism revealed no group difference across tasks. We found, however, a significant influence of IQ on grasp height modulation in both groups. These results provide clear evidence against a general prospective sensorimotor planning deficit and suggest that at least some form of higher order planning is present in autism without accompanying intellectual impairment.

1. Introduction

The ability to accurately anticipate and predict forthcoming actions and their effects is essential to solve daily sequential tasks, such as using a knife to spread jam on bread or grasping a bottle to pour a liquid without spilling it. A useful way to study this ability is to observe adaptations in one's behaviour as a function of the behaviour that follows. If an action differs depending on the subsequent action, then the anticipatory effect can be said to reflect *prospective sensorimotor control* (Ansuini et al., 2015; Rosenbaum et al., 2012).

Anticipatory changes of this sort have been studied extensively in object manipulation (Ansuini et al., 2008; Ansuini et al., 2006; Armbrüster and Spijkers, 2006; Becchio et al., 2012; Becchio et al., 2008; Cohen and Rosenbaum, 2004; Crajé et al., 2011; Johnson-Frey et al., 2003; Marteniuk et al., 1987; Rosenbaum et al., 1990, 1993; Sartori et al., 2009; Schuboe et al., 2008). For example, it is already well known that individuals tend to grasp objects differently depending on what they plan to do with the objects (Ansuini et al., 2015). A clear demonstration of prospective sensorimotor control for object manipulation is provided by the *grasp height* effect, i.e., the tendency to take hold of objects at a height that is inversely related to the height of the target location that they are attempting to reach (for review, see Rosenbaum et al., 2012). For example, when placing a book on a shelf, the higher the shelf, the lower individuals tend to grasp the book. Doing so has been shown to promote not just comfort of the end posture (i.e., end-state comfort) but also better control at the time of task completion (Rosenbaum et al., 2006). Thus, the initial grip of the book reflects an anticipation of the posture the body will be in once the target location of the action is reached.

Behaviours that reflect this effect have been reported when adult participants manipulate objects with only one hand (unimanual object manipulation; Cohen and Rosenbaum, 2004; Rosenbaum and Jorgensen, 1992; Weigelt et al., 2007) as well as when they use two (bimanual object manipulation; Haggard, 1998; Meyer et al., 2013; Rosenbaum et al., 1990). Moreover, there is evidence of grasp height effect in typically developing children from 7 to 12 years of age, with an increase of the effect as their age develops within this range (Janssen and Steenbergen, 2011).

A far less studied aspect of prospective sensorimotor control is the planning of cooperative actions with others. Acting jointly with another person requires one to consider and integrate not

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Table 1
ADOS-2 and ADI-R scores for participants in the ASD group.

Participant	ADOS-2			ADI-R				
	Total Score	SA	RRB	Total Score	A)	B)	C)	D)
1	*8*	6	2	30	*12*	*9*	*7*	*2*
2	*8*	6	2	28	*10*	*11*	*5*	*2*
3	*9*	8	1	25	*10*	*8*	*5*	*2*
4	*8*	6	2	28	*11*	*9*	*4*	*4*
5	*8*	7	1	31	8	*17*	*5*	*1*
6	*8*	7	1	49	*20*	*15*	*10*	*4*
7	*13*	11	2	21	9	*8*	*3*	*1*
8	*9*	8	1	41	*18*	*19*	*3*	*1*
9	*8*	7	1	30	*11*	*11*	*5*	*3*
10	*8*	7	1	24	*10*	*8*	*5*	*1*
11	*10*	8	2	29	*11*	*8*	*5*	*5*
12	*9*	8	1	32	*12*	*11*	*6*	*3*
13	*8*	7	1	24	*10*	*9*	*4*	*1*
14	*9*	8	1	24	*10*	7	*6*	*2*
15	*8*	7	1	25	*11*	*9*	*3*	*2*
16	*8*	6	2	24	*10*	5	*7*	*2*
17	*7*	6	1	27	*14*	3	*6*	*4*

Note: ADOS-2 (Autism Diagnostic Observation Scale 2) subtests: SA (Social Affect); RRB (Restricted and Repetitive Behaviors). Cut-off score for ADOS-2 Total Score (SA + RRB): (autism = 9; autism spectrum = 7). ADOS-2 Total score range (0–28). ADI-R (Autism Diagnostic Interview-Revised) subtests: A) Qualitative Abnormalities in Reciprocal Social Interaction (cut-off score = 10); B) Qualitative Abnormalities in Communication (cut-off score = 8); C) Restricted, Repetitive, and Stereotyped Patterns of Behavior (cut-off score = 3); D) Abnormality of Development Evident at or Before 36 Months (cut-off score = 1). ADI-R Total score range (0–78). The scores in Italics meet cut-off criteria.

only one's own but also their partner's next action (Sebanz et al., 2006). Consider, for example, one person handing books to another when filling a bookshelf together. Formalizing this example, Meyer et al. (2013) found that adult participants modulated the choice of the grasp height to accommodate not only their own end-state but also their action partner's end-state. This result has been taken to signify similarity in mechanisms underlying prospective control of individual and joint action sequences. However, the exact mechanism supporting joint action planning remains unclear. Do individuals represent their action partner's discomfort and therefore adjust their own actions accordingly? If so, does joint action planning depend on the ability to represent others' internal states? More broadly, does it relate to social functioning?

Abnormalities in social functions are a striking feature of autism, a neurodevelopmental disorder defined by characteristic deficits in social interaction and communication – so-called social symptoms. Even individuals with autism spectrum disorders exhibit deficits in coordinating gaze and action with others and understanding the mental states and social intentions of other people (Happé and Frith, 2014). Yet, this condition is also defined by a less well-researched range of non-social motor symptoms (Cook, 2016; for meta-analysis, see Fournier et al., 2010), including impairments in basic motor control (Adrien et al., 1993; Jansiewicz et al., 2006; Teitelbaum et al., 1998), difficulties performing skilled motor gestures (Mostofsky et al., 2006), abnormal patterns of motor learning (Haswell et al., 2009), and disturbances in the reach-to-grasp movement (Mari et al., 2003; Noterdaeme et al., 2002). Comparison between the performance of typically developing children and children with autism spectrum disorders may thus inform us about the link between prospective sensorimotor control, motor skills, and more complex socio-cognitive skills.

With this in mind, in the present study, we examined prospective planning for self and other people's actions in typically developing children and children with autism spectrum disorders without accompanying intellectual impairment. To study whether participants altered their initial grasp in anticipation of what they or their action partner planned to do with the object, we implemented a simple object manipulation task in which a cylinder had to be transported from a table (i.e., home position) to a shelf of varying height (i.e., target position). The number of moves varied depending on the task: unimanual, bimanual, joint. In the unimanual task, participants picked up the cylinder with their right hand and then moved it to the target position. In the bimanual task, they picked it up with their right hand and passed it to their left to move it to the target position. The joint task was similar, except that they picked up the cylinder with their right hand and passed it to a co-actor to move it to the target position. We used the height at which the cylinder was grasped (i.e., *grasp height*) as a *continuous measure* for prospective sensorimotor control across tasks. Grasp heights were analysed in a mixed factorial ANCOVA with *task* (unimanual, bimanual, joint) and *target position height* (low, middle, high) as within-subject factors, *group* (ASD, TD) as between-subject factor, and age, stature, and Full Scale IQ as covariates. In addition, to investigate whether prospective control was linked to motor, executive, and language function, in each group we correlated grasp height measures with standardized measures of motor skills, executive planning, and receptive vocabulary. Finally, we also correlated the grasp height measures with the severity of autism symptoms as measured by the Autism Diagnostic Observation Schedule.

2. Materials and methods

2.1. Participants

Seventeen children with Autism Spectrum Disorder without accompanying intellectual impairment (ASD group: 15 males) and 20 age-matched typically developing children (TD group: 16 males) were recruited from the Child Neuropsychiatry Unit of the 'Giannina Gaslini' Hospital and schools in Genova. All participants had normal or corrected-to-normal vision and were screened for exclusion criteria (dyslexia, epilepsy, and any other neurological or psychiatric conditions). Participants in the ASD group were diagnosed according to DSM-5 (American Psychiatric Association, 2013) criteria. The Autism Diagnostic Observation Scale (ADOS-2; Lord et al., 2012) and the Autism Diagnostic Interview-Revised (ADI-R; Rutter et al., 2003) were administered by two skilled professionals (a child neuropsychiatrist and a neuropsychologist). All participants met the cut-off criteria for ASD with respect to the total ADOS score and the communication and reciprocal social interaction subscales (see Table 1).

Groups were matched for age (ASD M ± SD = 9.9 ± 1.6 years.months; TD M ± SD = 9.5 ± 1.5 years.months; $t(35) = 0.804$, $p > 0.05$), gender (ASD M:F = 15:17; TD M:F = 16:20), stature (ASD M ± SD = 141.2 ± 8.7; TD M ± SD = 138 ± 9.1 cm;