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Preliminary Evidence for Inflexibility of Motor Planning in Children with Autism Spectrum Disorder

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Abstract

Background: Children with ASD often exhibit repetitive and stereotyped behaviors as well as difficulty performing motor actions. Difficulty in performing actions may stem from resistance to formulating new motor plans (persisting with previous motor plans even when new plans are needed for efficient movement). The aim of this study was to document flexibility of motor planning in individuals with ASD.

Method: Five children with ASD and 5 neurotypical control children performed a grasp-and-place motor task. In successive trials, a wooden rod was placed in one of 24 different orientations – rotating either clockwise or counterclockwise around a circular template. A child grasped the rod and moved it. The position where the child switched from thumb-toward one end of the rod to the other in each direction was recorded.

Results: Neurotypical children exhibited earlier grasp switches as well as a greater number of grasp switches as compared to children with ASD.

Conclusion: We found preliminary evidence that, for children with ASD, changing a grasp was more costly than being uncomfortable.

Keywords: Motor planning; Hysteresis; Autism spectrum disorder; Action costs; End-state comfort; Repetitive behavior

Introduction

Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder that can cause significant social, cognitive, and behavioral impairments [1]. Children with ASD also exhibit repetitive behavior patterns such as rocking back and forth and nail biting, and stereotyped behaviors such as lining up all their toys in a certain way according to size, shape and color [2]. While not a specific diagnostic criteria, a majority of individuals with ASD also exhibit difficulties with initiating, performing, mirroring, inhibiting and planning motor actions [3,4].

Motor actions, though not typically classified as communicative, can convey information about what a person will, or would like to do. A common example is the awkward grasp a waiter adopts to pick up an overturned glass in order to turn it over and, eventually, pour water into it. The awkward, initial grasp is informative about the task goal even before the task is completed. This type of awkward initial grasp followed by a more comfortable end-state grasp is referred to as end-state comfort [5]. Demonstration of end-state comfort implies that an initial grasp was planned with the comfort of the end state in mind. Neurotypical adults exhibit end-state comfort virtually 100% of the time [6]. In neurotypical children, end-state comfort increases with age and reaches adult-like values by age 10 [7].

In children with ASD, end-state comfort is not exhibited as frequently as in neurotypical children [8]. When asked to use an underhand grasp to lift and place one end of a rod into a stand, a group of children with ASD exhibited end-state comfort (thumb-up postures at the end-state) between 6 and 28% of the time [9]. In a similar study, children with ASD exhibited delayed activation of the mylohyoid muscle (used to open the mouth) when reaching for an object to bring it to the mouth [10]. These studies suggest that individuals with ASD did not use information about future motor actions to modify current motor actions. The inability to plan for future actions likely delays execution of subsequent motor actions and therefore alter interactions that depend upon proper interpretation and communication of motor plans.

Typically actions are performed in the context of (e.g. before or after) other similar actions. The decreased exhibition of end-state comfort in individuals with ASD may reflect either a decreased weighting of comfort as a main factor in action selection or difficulty in formulating motor plans that differ from those performed previously. In typically developing individuals, actions are influence by recently performed, similar motor actions [11]. Weigelt et al. [11] asked subjects to grasp and open nine drawers either from the top down or from the bottom up. The subjects who began with opening the bottom drawer initially used an underhand grasp on the drawer handle, and then switched at some point to an overhand grasp as they opened higher drawers. When starting from a higher drawer, an overhand grasp was used until some point when the underhand grasp was more comfortable. The interesting finding was that the point where the grasp changed from under to overhand or from over to underhand was different depending on the direction of the sequences of drawer grasping. This finding indicated that participants' choice of grasp was influenced by their previous history of grasping (called hysteresis) and also implies that, up until some point of maximal discomfort, it was more costly to change the motor plan for grasping than to endure the discomfort of a grasp that was less comfortable. In other words, repeating an action is cognitively simpler than creating an entirely new motor plan [12]. Although no work has been done specifically examining hysteresis in individuals with ASD, adults with ASD exhibited greater resistance to re-planning an action they had

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previously performed when they had prepared to perform an alternate action, indicating a cost to formulating a motor plan other than the one they had in mind [13]. The main aim of this pilot study was to examine the extent to which children with ASD resisted formulating new motor plans at the expense of using an uncomfortable posture.

Materials and Methods

Participants

Ten children ages 7-10 years old participated in the study. Five of the children were diagnosed with ASD, and five of the children were neurotypical (Table 1). Informed consent procedures were approved by the university Institutional Review Board (IRB). All participants signed informed assent, and parents of each child signed an informed consent to allow their children to participate. These children were recruited from a longitudinal study examining narrative understanding in children with ASD. The sample was a convenient sample and included two females and three males.

Apparatus and task

Each child was seated at a table. In front of the child on the table, were two pieces of paper, 21.59*27.94 cm. The first paper had a circular template printed on it. This circular template had twenty-four corresponding numbers around the diameter, each 15° apart. The second paper was place directly above the circular template and had a printed black rectangle the same size as a wooden dowel rod printed on it. This rectangle was referred to as the "home position" (Figure 1). A wooden dowel rod was place on the circular template at a certain orientation. The wooden rod was colored half white and half black, or half red and half blue.

Procedures

Initially, the experimenter put a binder between the child and the circular template to prevent the child from seeing the orientation of the wooden rod in advance. The wooden rod was then placed on the circular template. The binder was removed and the experimenter asked the child to return the rod to the "home position". The child grasped the rod, lifted it, and returned it to the "home position". Then, the binder was replaced to occlude the child's vision, and the rod was placed back on the circular template in a new orientation – either 15° counter-clockwise or clockwise from the previous orientation – and the task was repeated (Figure 2). This was completed for 25 successive positions; the final vertical position (25) was the same as the beginning vertical position (1). Each child completed the task four times, twice clockwise and twice counterclockwise, once with the black and white rod and once with the red and blue rod. Each day both orders were performed with one color. The rotation with the black and white rod was always performed first.

Data Collection and Scoring

Videos were taken of each session to allow for later scoring. Two experimenters independently rated the thumb position upon rod grasp as well as which hand was used. An initial thumb position change from the thumb-toward one end of the rod to the other on successive trials was identified as a grasp switch. A grasp transition was defined as an initial thumb position change from one end of the rod to the other end on successive trials in circumstances where the grasp switch also led to a more comfortable grasp – thumb up or thumb in vs. thumb down or out – (Figure 3). A grasp transition was also documented as a grasp switch. If a participant switched from one hand to the other hand but the thumb remained facing the same end of the rod as the previous grasp, a hand switch, but not a grasp switch was documented.

Participant	Age (years, months)	Gender	Matched Control Age (years, months)
1	10, 8	Female	10, 2
2	10, 9	Male	10, 11
3	9, 5	Female	8, 5
4	8, 4	Male	7, 11
5	9, 6	Male	9, 2

Table 1: Age and gender for all participants and matched controls.

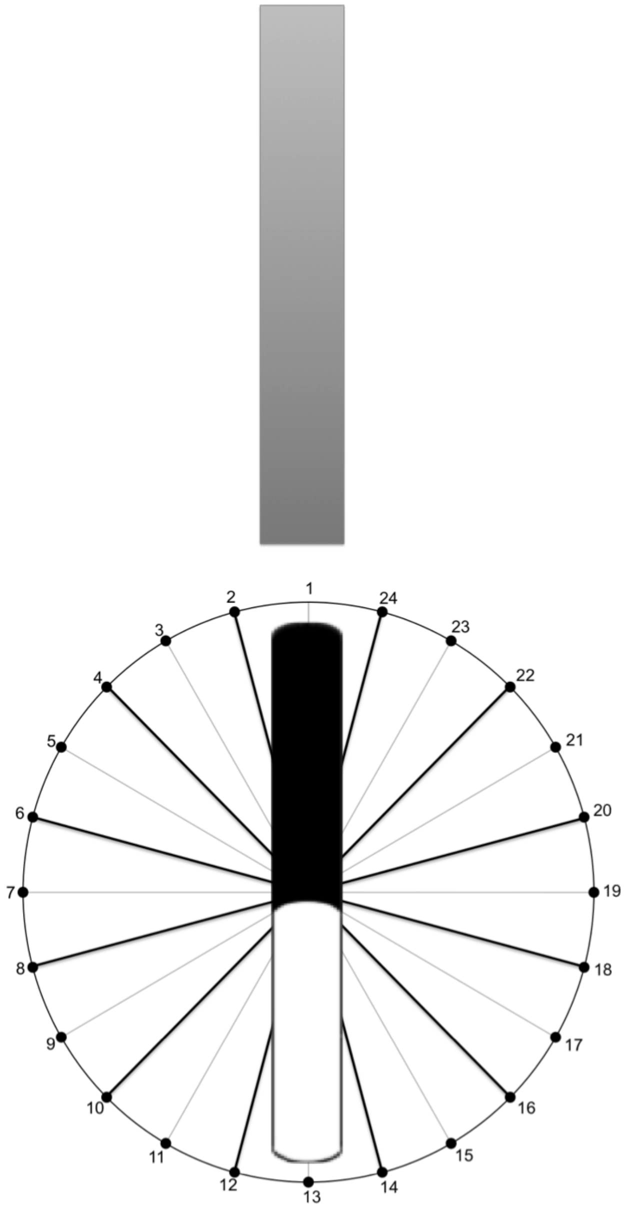

Figure 1: A representation of the experimental task with the rod oriented at position 1.

Results

All participants made the first grasp with their right hand. Only one

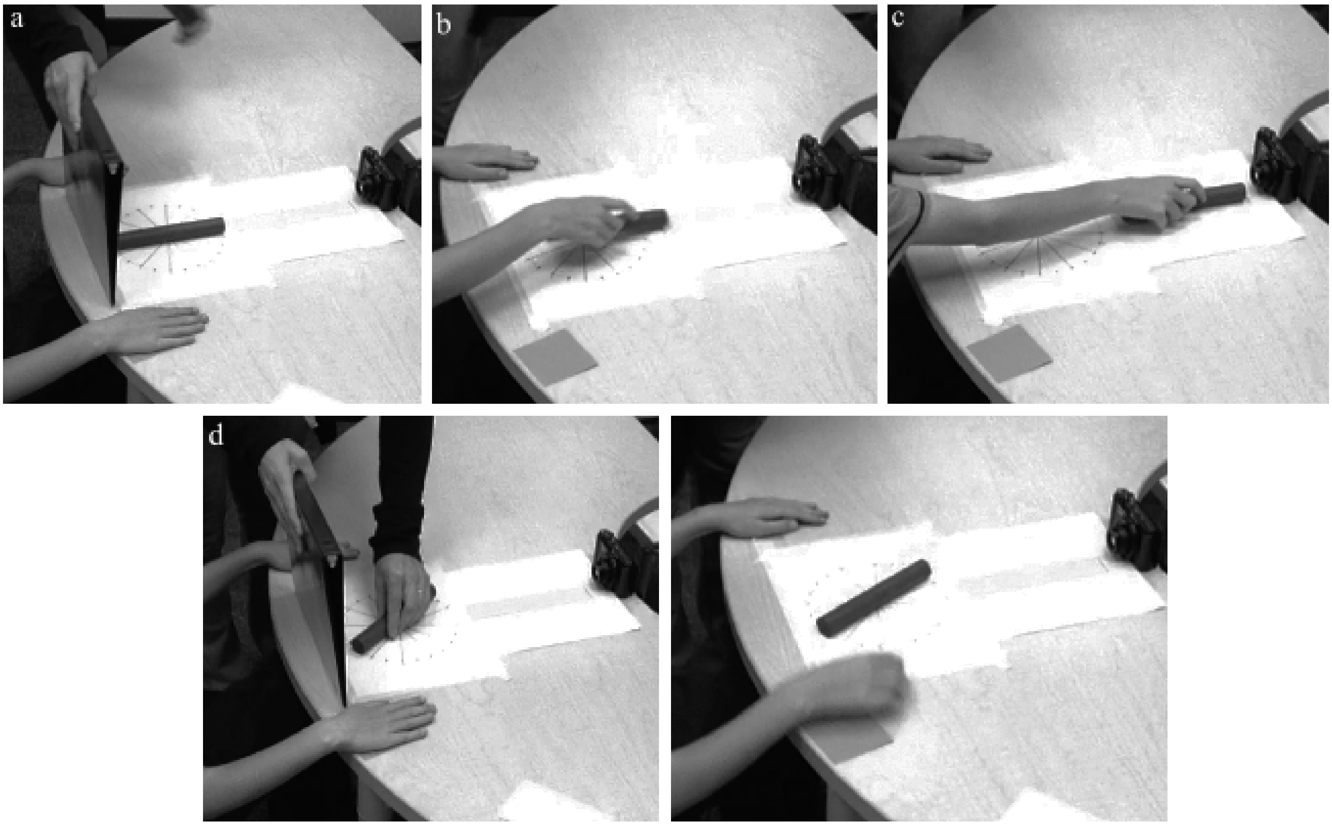

Figure 2: Task procedure a) the binder is placed in front of a participant and the rod is placed in one orientation, b) the binder is removed and the participant grasps the rod and c) places it in the home position, d) The binder is placed in front of a participant and the rod is placed in a new orientation and e) the binder is again removed.

participant made a first grasp with a thumb-toward-white grasp. This participant made a thumb-toward-black grasp on position 2; therefore, his first transition was calculated as the point after this at which he switched to a thumb-toward-white grasp. Only one participant for one trial chose to switch hands rather than grasps, in order to make the task more comfortable. In two cases, participants in the neurotypical group chose to grasp the rod with their left hand leading up to a transition for the CCW direction, but not for the CW direction. For these two participants, only one session of data was used for the hysteresis analyses.

The sum total of grasp switches that occurred at each dowel rod position for all participants and both trials of each rotation direction were plotted (Figure 4). The peak switch position (the position where the greatest number of grasp switches occurred) occurred for children with ASD at position 13 for both the clockwise and counter clockwise rotations (Figures 4a and 4b). This represented the half way portion around the circle. Neurotypical children had a much earlier peak grasp switch for the clockwise rotation (22) than children with ASD (13) and a much wider distribution of grasp switches with peaks at 11 and 25 for the counterclockwise rotation (Figure 4). Neurotypical children exhibited a greater number of grasp switches during both CW and CCW rotations. A summary of grasp behavior is presented in Table 2.

In addition to the sum total of grasp switches, we calculated the hysteresis distance. Hysteresis is defined as "a directional dependence in an observed transition" [14]. In our experiment the switch from a thumb-toward black to a thumb-toward white transition or vice versa – may have occurred at a different dowel rod position based on which rotation direction was being performed. For example, during the clockwise rotation, one participant (Figure 3) used a thumb-toward-black grasp until position 20 and then switched to a thumb-toward-white grasp on position 19. When rotating the other direction, this participant switch from thumb-toward-white to thumb-toward-black at position 22, 3 positions later than the switch occurred during the CW rotation. The hysteresis distance for this transition would thus be 3. For each participant and session the hysteresis distance was calculated. Typically, two transitions occurred during each trial. Hysteresis distance for both transitions and both sessions were averaged for each participant and then over participants in each group. The distance was 1.4 positions greater for children with ASD than for neurotypical children (Table 2). Due to our small sample size, a difference between these two scores was compared using a Wilcoxon two sample exact test, Z=0.42, p=0.65, but was not significant. Two children with ASD – one male and one female exhibited large hysteresis effects, indicating that some children may exhibit greater hysteresis than others.

ANOVA's were run using group (children with ASD vs. neurotypical children) and rotation direction (CCW vs. CW) as factors on the average distance in degrees between grasp transitions and the average distance in degrees to the first grasp transition. Despite low sample number, assumptions of normality and homogeneity of variance were met for both variables. Children with ASD exhibited greater distance between grasp transitions than neurotypical children for the clockwise rotation (Table 2). This is supported by a significant group by rotation direction

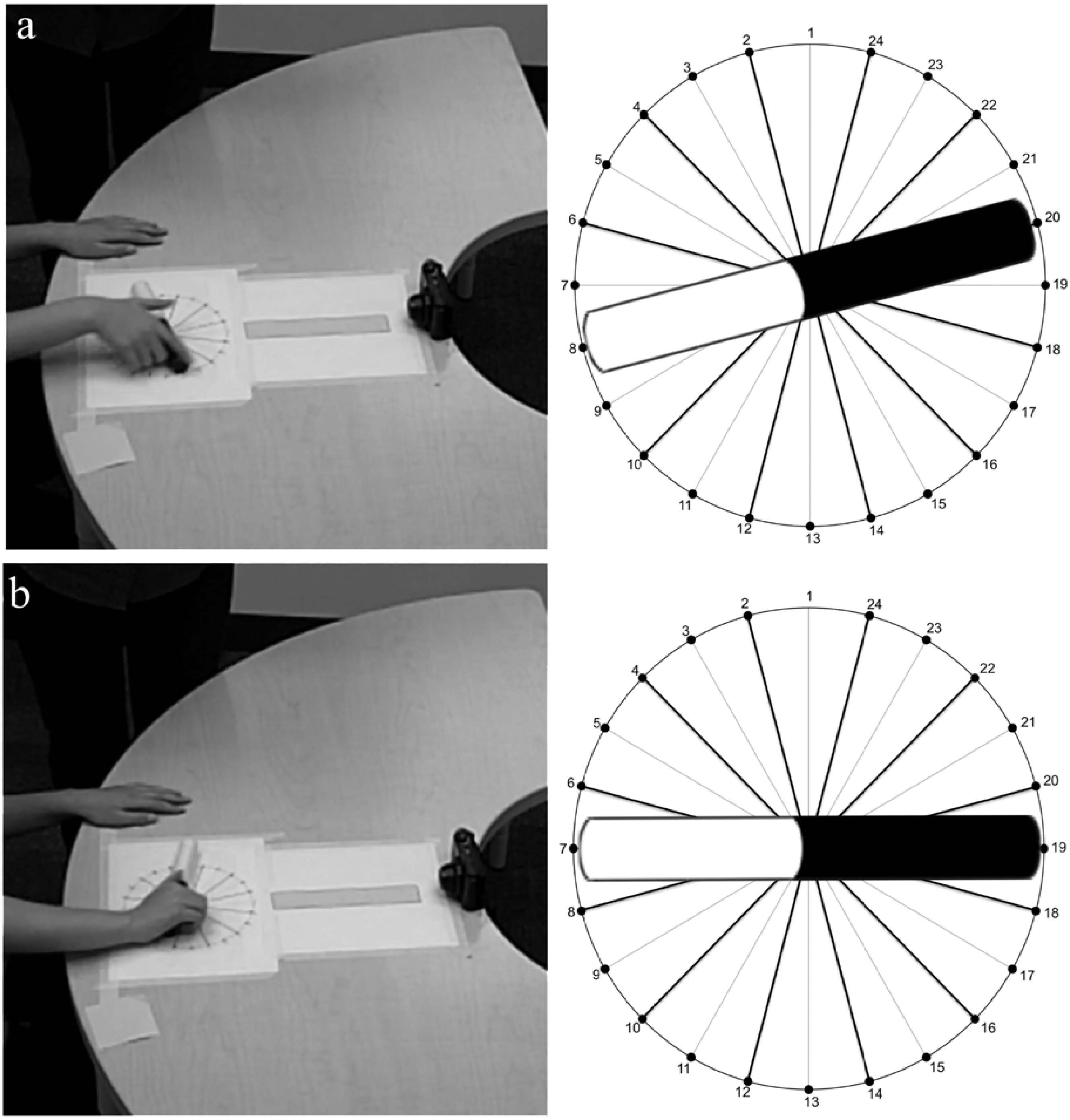

Figure 3: Example of a grasp switch occurring, for the CW rotation, on rod position 19. The participant switched from a thumb-toward-black (a) to a thumb-toward-white grasp (b).

interaction, $F(1,8)=27.8$; $p=0.0008$, $\eta_p^2=0.78$, and a significant contrast between groups for the clockwise rotation, $F(1,8)=49.9$, $p=0.0001$, $\eta_p^2=0.86$. Children with ASD also exhibited greater distance from the start of the task to when they exhibited their first transition than did neurotypical children (Table 2). This is supported by a significant main effect of group, $F(1,8)=5.74$; $p=0.04$, $\eta_p^2=0.42$. For distance to first transition there was also a main effect of rotation direction, $F(1,8)=27.8$; $p=0.0008$, $\eta_p^2=0.78$, exemplifying the more awkward postures needed to maintain a thumb-toward-black grasp when the rod rotated in a clockwise direction.

Discussion and Conclusion

The main aim of this study was to document differences in grasp planning between children with ASD and neurotypical controls.

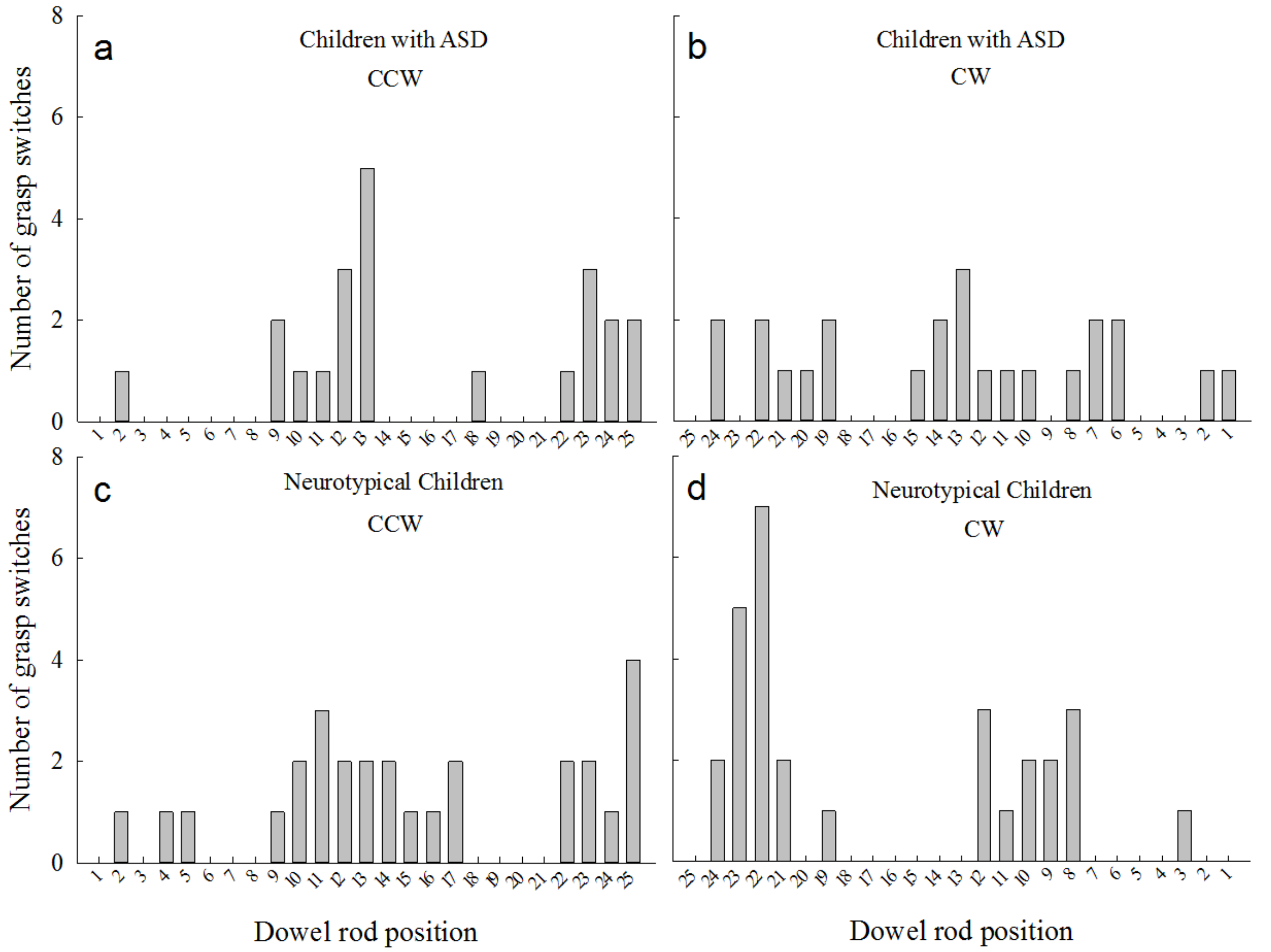

Figure 4: Plots of the sum total number of grasp switches that occurred at each dowel rod position for children with ASD (a and b) and neurotypical children (c and d) performing the counter-clockwise rotation and clockwise rotation.

Group	Rotation Direction	Sum of grasp switches	Sum of hand switches	Distance between transitions (degrees)	Position of first transition (degrees)	Hysteresis distance
Children with ASD	CCW	22	7	170	177	3.2
	CW	24	8	161	75	
Neurotypical Children	CCW	28	9	173	159	1.8
	CW	29	8	188	36	

Table 2: Descriptive data.

Overall, children with ASD maintained a chosen grasp longer – switched their grasp positions later – and changed grasps less frequently than neurotypical children. These results suggest that changing a grasp may have been more costly for children with ASD than for neurotypical children while maintaining an awkward/uncomfortable posture was not as costly. In general, the greater number of and earlier exhibition of grasp switches that occurred for the neurotypical children versus those with ASD indicates greater flexibility of motor planning.

Current diagnostic criteria for ASD look at measures such as stereotyped behavior, communication, and social interaction. There is currently no established method for evaluating deficits in motor planning. However, much of communication is nonverbal, and motor skills develop earlier than verbal skills in children. Previous studies have found associations between early oral and motor skills and speech fluency in children with ASD [15]. These early disturbances in motor planning for children with ASD could impact how the child plays, explores, and engages socially [16], potentially impaction social communication as a whole.

Our research provides the first evidence that motor-planning deficits could be a key feature of ASD that might be incorporated into diagnosis, treatment, and delineation of further subtypes of ASD. Of even greater impact is learning how motor planning might develop in sequence with other diagnosis criteria of ASD such as stereotyped behavior, verbal communication, and social interaction. Many clinicians are now proposing a multisystem approach to ASD intervention focusing on non-verbal and social communication [17]. Furthermore, there is a call among practitioners for more targeted measurement of specific motor impairments in individuals with ASD [18]. This preliminary project lays the foundation for further exploration of motor function in children with ASD across age groups and disability levels.

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