Social Cues affect Grasping Hysteresis in Children with ASD

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Abstract

Healthy development leads to a fluid integration of competing constraints. A marker of such behavior is hysteresis, reflecting a multi-stable system that takes into account its immediate history. The current study investigates patterns of hysteresis in typically developing children (TD) and those diagnosed with Autism Spectrum Disorder (ASD). The task was to grasp and lift objects that increased in size, either from smallest to largest, or from largest to smallest. The objects could be picked up with one or two hands, marking a range of bi-stable behavior. Results of the grasping task showed hysteresis in TD children, whether or not the task was situated in the social context. In contrast, children with ASD showed hysteresis only in the non-social context. For both diagnostic groups, perseveration did not correlate to the degree of hysteresis, regardless of the presence or absence of social cues.

Keywords: multi-stability; motor behavior; autism

Introduction

Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder that is characterized by significant impairments in social interactions and the presence of restricted patterns of behaviors and interests (APA, 2013). To date, no definitive cause of ASD has been identified. ASD may relate to an inability to take the perspective of others (e.g., Baron-Cohen, Leslie, & Frith, 1985); it may relate to a tendency to focus on details in their environment, as opposed to on overall impressions (e.g., Happé & Booth, 2008); or there might be neurological differences that drive the ASD deficits (e.g., McPartland, Wu, Bailey, Mayes, Shultz, & Klin, 2011). Differences in the ability to share attentional focus with others (e.g., Meindl & Cannella-Malone, 2011), difficulty reacting to social cues (Loveland, 1991), and deficits in executive function (e.g., Ozonoff. 1997) have also all been argued to lie at the heart of ASD.

Rather than focusing on an isolated cause, we argue that human functioning (typical or atypical) can be understood as patterns of coordination on all levels of behavior, including the neurological, perceptual cognitive, and social levels. It is the complex interplay between microscopic and macroscopic factors that drives behavior, ranging from coordination between various regions of the brain (e.g., Minshew & Keller, 2010), coordination of representations during problem solving (Stephen et al., 2009), and coordination between social partners (e.g., Marsh et al., 2009).

There is evidence that coordination may differ between typical development (TD) and ASD. For example, there is growing evidence that, on the neurological level, ASD may be more related to diffuse, connective differences coupled with differences in neural activation patterns (e.g., Belmonte et al., 2003; for a review, see Minshew & Keller, 2010). Differences are also evident in tasks that involve interpersonal motor coordination (e.g., Marsh et al., 2009). Specifically, while TD children have a tendency to inadvertently sync their movements with others, children with ASD do not.

In the current study, we expand on these findings by looking at the moment-to-moment emergence of coordination in a grasping task. Specifically, we look at the degree to which a pattern of behavior is affected by preceding patterns of behavior, either by showing a lagging, indicative of *hysteresis* (e.g., Guastello & Liebovitch, 2009), or by showing anticipation, indicative of *enhanced contrast* (Kelso, 1995). Both hysteresis and enhanced contrast are considered flags of complex systems. They have been demonstrated in perception of speech categorization (Tuller, Case, Ding & Kelso, 1994) and motor behavior (e.g., Frank, Richardson, Lopresti-Goodman, & Turvey, 2009; van der Kamp et al., 1998), among other domains. In the current study, we are using the paradigm of a grasping task to describe behavioral coordination in ASD.

Grasping can require one or two hands, depending on the size of the object that is being moved. With smaller objects, it is inefficient to use two hands for grasping, while with larger objects it becomes increasingly necessary to use two hands. The transition between one- and two-handed grasping, as the size of objects increases, demonstrates the system's ability to organize itself beyond an individual trial (e.g., Frank et al., 2009). Importantly, the transition between grasping styles occurs at different object sizes when objects are presented in a descending versus ascending order (e.g., Richardson, Marsh, & Baron, 2007; van der Kamp et al., 1998).

The current study explores how grasping patterns in children with ASD and TD are affected by (1) the presence or absence of social factors, and (2) general mental flexibility. There is evidence that children with ASD demonstrate perseveration (e.g., Rajenran & Mitchell, 2007). We question whether hysteresis is a form of perseveration.

Methods

Participants

The sample consisted of 41 6- to 10-year-olds (35 boys) who met diagnostic criteria for ASD and 42 TD 6- to 10-year-olds (31 boys), group-matched by chronological age. There was a significant difference in IQ (i.e., GCA of the DAS-II; Elliott, 2007; IQ_{ASD} = 98.9; IQ_{TD} = 108.6), $t(81) = 3.04$, p = .003). There was also a marginally significant difference in mental flexibility (measured as Wisconsin Card Sorting Test, Computerized Version 4: WCST; Heaton, 2005; Perseverative Error Standard Score: $PERS_{ASD}$ = 98.00; $PERS_{TD}$ = 104.33, $t(66) = 1.73$, $p = .09$). Age was positively correlated to PERS for TD children, $r(34) = .40$, $p = .016$, but not for ASD children, $r(30) = .14$, $p = .45$. IQ was marginally correlated to PERS for TD children, $r(34) = .28$, $p = .093$, and positively correlated for ASD children, $r(30) = .41$, $p = .019$.

Stimuli and Setup

Stimuli consisted of 19 foam-board cubes, ranging in size from 2 to 20 cm wide. The material made it possible for children to pick up cubes easily (with either one or two hands). No participants indicated any difficulty lifting the cubes.

A low table was used, partitioned by 30 cm high curtains (see Procedure). A rotating wooden dolly, 36" in diameter, was used in the non-social context. It was placed to the child's left, such that part of its surface was occluded by one of the curtains.

Design and Procedure

During the first visit, a battery of clinical measures was administered. During the second visit, children completed the grasping task (in addition to other tasks not reported here), followed by the WCST.

For the grasping task, two experimenters were present: E1 and E2. The child sat across from E1, with E2 sitting behind a curtain, to the child's right, and outside of the child's view. During a trial, E2 pushed a cube through the curtain towards the child (without picking it up). In the non-social context, the child was asked to pick up the cube and place it on the dolly. In the social context, the child had to pick up the cube and hand it to E1 (who held out either one hand or two, depending on condition), in approximately the same location as the dolly. For each trial, E1 recorded whether the child picked up the cube with one or two hands. Cubes were presented in two phases. In the ascending phase, participants were first presented with the 2 cm cube, followed by successively larger cubes. It ended when five consecutive cubes were picked up with two hands. In the descending phase, they first saw the 20 cm cube, followed by successively smaller cubes. It ended when five consecutive cubes were picked up with one hand.

All participants completed the non-social and social conditions in a fixed order. Each participant was randomly assigned to one of two presentation orders (ascending phase first or descending first) and one of two hand conditions (E1 extends one hand or two hands in anticipation of the cube).

Results

The central questions pertained to whether children showed hysteresis, as determined by whether their grasping pattern changed on a larger cube in the ascending phase than the descending phase. A transition point was calculated in each phase, to determine the cube size at which the grasping pattern changed during a phase (cf. Lopresti-Goodman, Richardson, Baron, Carello, & Marsh, 2009; Van der Kamp et al., 1998). There were four transition points for each child: one for the ascending phase and one for the descending phase in both the non-social and social contexts. Figure 1 shows the averages of obtained transition points.

On the basis of preliminary analyses, we collapsed data across order and condition for the non-social context, and we collapsed data across order for the social context. A 2 (diagnosis) X 2 (ascending vs. descending phase) X 2 (social vs. non-social context) mixed-design ANOVA revealed a significant main effect of phase, $F(1,81) = 23.97$, $p < .001$, with children transitioning on higher cubes in the ascending ($M = 11.04$) than the descending phase ($M = 9.98$). The main effects of diagnosis and context were not significant, *p*s > .14. However, there was a significant diagnosis-context interaction, $F(1,81) = 3.99$, $p = .049$, with TD, but not ASD children transitioning on larger cubes in the non-social context than the social context. All other interactions failed to reach significance, *p*s > .13. To follow up on these effects, we examinded the effect of hysteresis for each context separately.

Non-Social Context

As expected, a 2 (diagnosis) x 2 (phase) mixed-design ANOVA revealed a main effect of phase, $F(1,81) = 22.33$, $p < .001$, with a higher transition point in the ascending (M = 11.25) than the descending phase (M = 9.87). There was also a main effect of diagnosis, $F(1,81) = 5.66$, $p = .02$, with a higher mean transition point for TD children (M = 11.10 cm) than ASD children (M = 10.02 cm). Importantly, there was no diagnosis-phase interaction, $p > .73$, indicating hysteresis in both diagnostic groups. This finding was further supported by simple effects: Both TD and ASD children transitioned on a larger cube in the ascending than the descending phase, *p*s < .001.

Social Context

A 2 x 2 x 2 mixed-design ANOVA was carried out, with diagnostic group (TD vs. ASD) and condition (one-hand, two-hand) as between-group factors, and phase as the within group factor (ascending vs. descending). There was again a main effect of phase, $F(1,81) = 10.33$, $p < .04$, there was also a marginal diagnosis-phase interaction, $F(1,81) = 3.33$, $p < .09$. This interaction indicates that hysteresis was not equally present in both diagnostic groups. To follow up on this effect, we look at each diagnostic group separately.

Considering TD children first, a 2 (phase) x 2 (condition) mixed-design ANOVA revealed a significant effect of phase, $F(1,40) = 5.73$, $p = .022$, with a higher transition point in the ascending phase (M = 11.20) than in the descending phase (M = 9.89). There was no effect of condition, $p > .30$, and no significant interaction with condition, $p > .50$. Thus, regardless of whether the experimenter held up one or two hands when receiving the cube, TD children showed evidence of hysteresis.

Now consider ASD children. Here, the 2 x 2 mixed-design ANOVA revealed no effect of phase, $p > .76$, or condition, $p > .48$; and there was no interaction with phase, $p > .66$. Whether cubes were presented in the ascending- or descending-first order, the transition point did not change. Thus, across both social-context conditions, children with ASD transitioned on similarly sized cubes in both the ascending and descending phases, failing to demonstrate hysteresis in the social context. These results are very different from what was found with ASD participants in the non-social context. A 2 by 2 (context x phase) repeated-measures ANOVA (with data collapsed across condition) revealed a significant phase-context interaction, $F(1,40) = 5.05$, $p = .03$. Thus, the pattern of performance for children with ASD differed significantly between the non-social and social contexts.

Individual Patterns of Performance

Are group results of hysteresis supported by individual patterns of performance? To address this question, we determined the difference between ascending-phase transition point and descending-phase transition point for each child. A positive transition difference indicates hysteresis (i.e., later transition in the ascending than the descending phase). By comparison, a negative transition difference indicates enhanced contrast (i.e., earlier transition in the ascending than the descending phases. No difference indicates that the child is switching grasping method at the same sized cube for both ascending and descending phases.

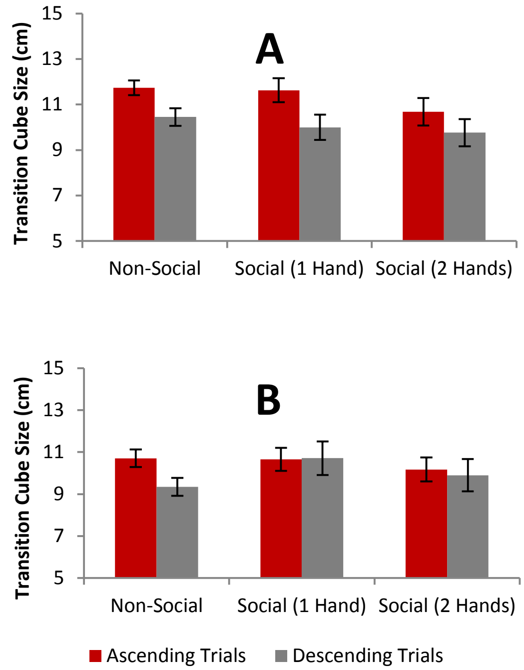

Figure 1: Mean transition point, in centimeters, for the non-social and social context, separated by ascending versus descending trials, and separated by diagnostic group: TD (A) vs. ASD (B)

Figure 2 shows the two transition differences calculated for each child (depicted as scatterplots of transition difference obtained for the non-social context vs. social context). By simply glancing at the figures, a difference in distributions is apparent: While the distribution of scores along the x-axis is comparable across the two diagnostic groups (non-social context), there is a clear shift in values along the y-axis (social context).

Indeed, a majority of TD and ASD children showed hysteresis in the non-social context (TD: 25/42 = 60%; ASD: 27/41 = 66%), consistent with the aggregate results. When looking across contexts, we see that one third of TD children showed hysteresis in both contexts (14/42 = 33%), while eight children showed no hysteresis in any contexts (19%). The same pattern held for ASD children: about one third showed hysteresis in both contexts (12/41 = 29%), while only nine children showed no hysteresis in any contexts (22%). Importantly, about the same number of the remaining TD children showed hysteresis in the non-social context only (11/42 = 26%) versus in the social context only (9/42 = 21%). In contrast, there were three times more ASD children who showed hysteresis in the nonsocial (15/41 = 37%) compared to social context only (5/41 = 12%). While these findings are not statistically significant, they nevertheless mimic the findings documented in the aggregate results.

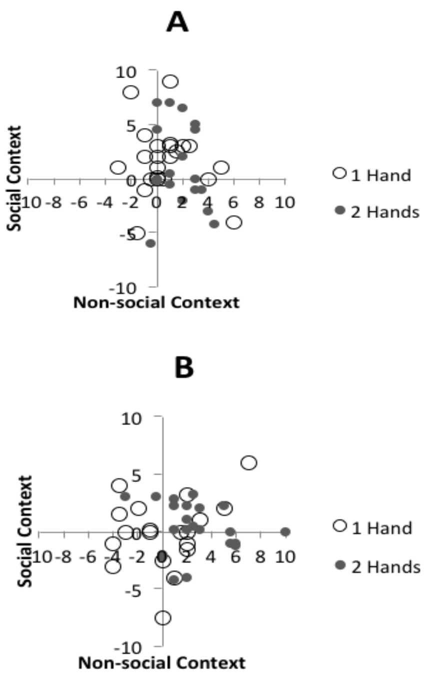

Figure 2: Scatterplot of transition differences in the non-social and social contexts for TD children (A) and children with ASD (B).

Hysteresis vs. Perseveration

There is evidence that children with ASD have a tendency to perseverate (e.g., Rajendran & Mitchell, 2007). To what extent are the processes that govern hysteresis the same processes that govern perseveration? To answer this question, we correlated the PERS scores with the transition differences obtained in each of the two contexts. Results show no significant correlations, *p*s > .15. In fact, the correlation obtained for ASD children in the non-social context was opposite of what would be predicted by a model that equates hysteresis with perseverative errors.

Discussion

Hysteresis is often considered to be an indication of the way in which a system transitions between two, adaptive, stable patterns, in the face of changing environmental constraints. For the current paradigm, this pattern is maintained in TD children across nonsocial and social contexts. However, for children with ASD, it breaks down in the presence of what could be argued to be very minimal social cues.

In typical development, the degree to which individuals demonstrate hysteresis during grasping tasks can be affected by contextual factors such as object presentation speed. Additionally, when participants are distracted, they demonstrate more hysteresis (Lopresti-Goodman et al., 2009). It is possible that in the presence of a social situation, children of ASD actually focused more on the task than they did in its absence, resulting in less hysteresis. However, this is speculative, as no measurements that could shed light on attentional focus (e.g., eye gaze) were gathered.

It was hypothesized that the degree to which a child demonstrated hysteresis during the grasping task would correlate to the amount of perseveration they exhibited on the WCST. However, hysteresis and perseverative errors were not correlated for either diagnostic group in both the social and non-social contexts. This is consistent with previous work that has argued that hysteresis and perseveration are separate concepts (e.g., Van Bers, Visser, van Schijndel, Mandell, & Raijmakers, 2011).

When considering the implications of this study's results, one must do so within the context of its limitations. First, with regards to the Grasping Task: the non-social and social contexts were in a fixed order, with the non-social context always first. This was initially chosen because of the fact that to our knowledge, no prior studies had explored hysteresis in ASD utilizing a grasping paradigm. Therefore, it was thought that if children ended their participation early, data may still be available for the non-social context. This would at least provide basic information about grasping hysteresis in ASD. But, this posed a potentially significant limitation.

The design of the Grasping Task limited the ability to determine whether performance in the social context may have been related to an order effect. On the one hand, it would be plausible that an order effect might correspond to more hysteresis due to task disengagement. However, if learning occurred, it is possible that children began to anticipate each successive cube, and therefore be more likely to demonstrate enhanced contrast. It is difficult to conjecture in either direction given that the diagnostic groups did not perform similarly across contexts.

Considerations must also be given when examining performance on the Grasping Task as compared to the WCST. Although it is thought to assess problem solving and mental flexibility, the WCST involves other cognitive processes which may affect performance, such as attention, working memory, and behavioral inhibition (e.g., Dehaene & Changeux, 1991). Also, most participants from the TD and ASD groups demonstrated IQs and WCST scores which were considered to be in the typical range of performance, clinically. Past work as suggested that ASD performance on the WCST may be related to intellect (e.g., Kaland et al., 2008). Finally, there is some evidence individuals with ASD perform better on the computerized version of the WCST than the standard version (e.g., Ozonoff, 1995).

Future work should explore whether the current study's results were due to an order effect. Counterbalancing the social and non-social contexts or introducing a distractor task (such as a condition in which the blocks are presented in a random order) would be beneficial. To address issues with the WCST, including groups of children with wider ranges of functioning, or considering a model in which half of the children take the computerized WCST and the other the standard version. Alternately, it might be helpful to include other measures of perseveration or executive functioning.

It will be important to also include physical measurements of participants' hands. Past research has described body-scaled characteristics associated with the transitions between grasping styles in TD children. That is, transitions in grasping occur at a relatively consistent ratio of cube to hand size. Scaling provides evidence that such behavior emerges as a result of complex self-organization that occurs between organisms and their environments in the absence of conscious thought (e.g., Frank et al., 2009; Van der Kamp et al., 1998). Thus, including such data will help determine whether or not the same body-scaling occurs for children with ASD as TD, which may provide more evidence for the coordination account of ASD.

Given its limitations, the current project was able to shed some light onto the way coordination emerges in ASD as it compares to TD. Specifically, children with ASD were able to complete the task in both the non-social and social conditions. However, their performance patterns were sensitive to the presence or absence of a social cue. Thus, as opposed to providing evidence for global deficits in either social or motor functioning, it suggests differing patterns of coordination between domains.

This study adds to the existing literature in important ways. First, it takes a novel conceptualization in studying ASD. It does not take a reductionist approach to symptomology, instead favoring a developmental one stemming from a dynamic systems perspective. Such a novel viewpoint may help unify many of the conflicting findings associated with ASD task completion. The varied performance of individuals with ASD on different tasks as often considered problematic because of the search for a core deficit. If such tasks are approached through the lens of the coordination account, focus shifts to the effect of contextual factors on *how* tasks are completed. Thus, differences in performance can be explained through a common phenomenon.

To function adaptively, the mind connects past events with each other. This connection between events allows us to form categories, learn a language, and engage in higher-order thought. If each experience would remain separate, it would be difficult to generalize information or to make predictions. The connections between experiences, which can be conceptualized as a form of coordination, emerge spontaneously. This study provides preliminary evidence that the ways in which contextual factors affect these patterns differs between TD children and those with ASD.

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