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Brief Report: Performance on the Dimensional Change Card Sort and Backward Digit Span by young children with autism without intellectual disability

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Abstract

The early development of executive function (EF) and its relation to autism symptom expression is of considerable theoretical interest, particularly in children without general cognitive delay. Executive function was tested in 23 children with autism spectrum disorders (ASD) without intellectual disability and 20 age- and IQ-matched typically developing children. Even though performance was equivalent between the two groups on tests of general intelligence, flexibility in card sorting was lower for children with ASD. Verbal working memory during the backward digit span did not differ between groups. Among children with ASD, poorer performance on card sorting distinguished a subgroup with worse social-communication functioning above and beyond IQ. With IQ controlled, social and repetitive symptoms of ASD did not differ based on card sorting ability.

Keywords

autism; executive function; working memory; flexibility; symptoms; repetitive behaviors

In order to effectively respond to the environment, executive function (EF) is necessary to hold complex or conflicting details in mind, flexibly adapt to feedback, inhibit inappropriate responses, and strategize about outcomes. These interrelated cognitive processes are impaired among individuals with autism spectrum disorders (ASD), even in the absence of intellectual disability (see Hill, 2004; Kenworthy, Yerys, Anthony, & Wallace, 2008; Pennington & Ozonoff, 1996 for reviews). While not a core symptom of ASD, which is characterized by social communication impairments and restricted repetitive behaviors

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(American Psychiatric Association, 2000), EF may contribute to social skill development (Pellicano, 2010). Despite much research addressing the executive impairments of individuals with ASD, questions remain.

First, little is known about EF in very young children with ASD without developmental delay. All but three studies of EF in children younger than seven (Pellicano, 2007; Pellicano, Maybery, Durkin, & Maley, 2006; Smithson et al., 2013) are limited by the inclusion of children with ASD who also had general cognitive delays (e.g., Dawson et al., 1998, 2002; McEvoy, Rogers, & Pennington, 1993; Yerys, Hepburn, Pennington, & Rogers, 2007). Thus, although children with ASD are first distinguished from mental age matched typically developing *and* developmentally delayed children in inhibition, visual working memory and flexibility by preschool (Dawson et al., 1998; McEvoy et al., 1993), it is unclear whether EF difficulties are associated with ASD *per se* or the combination of ASD and cognitive delay. Two studies of EF among 4–7 year olds with ASD in the absence of cognitive impairment also demonstrated lower inhibition and shifting ability as well as reduced planning capacity. However, both used the same test battery. The third study reported more widespread EF impairments based on parent report and a different pattern of EF than that found among older individuals with ASD (Smithson et al., 2013). Thus, at a period when typically developing children are rapidly gaining EF, knowledge of the early profile in ASD remains limited. Specifically, it is unclear whether shifting, which is commonly impaired among older individuals, is reduced for a variety of tasks. Second, an aspect of EF that is relatively spared among older individuals with ASD is verbal working memory, despite early and persistent impairments in visual working memory (Kenworthy et al., 2008) and parent report of significant working memory difficulties among preschoolers (Smithson et al., 2013). Verbal working memory performance has not been measured in young non-cognitively delayed children with ASD, and doing so would provide information about the stability of a non-unitary profile of EF impairments beginning early in the development of children with ASD.

Second, the relation between EF and functioning in other domains for young children with ASD remains surprisingly poorly understood independent of cognitive delay. Prior work with older children (e.g., Joseph & Tager-Flusberg, 2004; Kenworthy, Black, Harrison, della Rosa, & Wallace, 2009) suggests that EF may relate to social communication symptoms. In addition to direct measurement of symptoms, the relation between EF and more broadly conceptualized social function has also been tested. Cross-sectional and longitudinal evidence suggests EF at 4–7 years predicted later theory of mind performance above and beyond verbal and nonverbal cognitive ability and initial theory of mind ability, while theory of mind did *not* predict later executive ability (Pellicano, 2007; 2010). Investigations of the relation between EF and repetitive symptoms have included a wide range of ages, executive tasks and measures of repetitive behaviors and, unsurprisingly, have yielded mixed results (Dichter et al., 2010; Lopez, Lincoln, Ozonoff, & Lai, 2005; Mosconi et al., 2009; Reed, Watts, & Truzoli, 2011; South, Ozonoff, & McMahon, 2007; Yerys et al., 2009). Except for Reed et al. (2011), studies that reported a direct relation with EF measured lifetime repetitive symptoms, suggesting that behaviors present *earlier* in development may relate to current EF. The only examination of EF and symptoms in the social and repetitive

domains among 4–7 year olds with ASD without cognitive impairment did not detect relations (Pellicano et al., 2006), but raised the possibility that this could be due to reliance on only parent report of symptoms. Thus, it is important to test this relation. Understanding how EF might relate to symptoms and, more broadly, to social functioning among younger children would benefit from using a wider range of measurements.

The current study had two goals. The first was to compare young children with ASD to a group of age- and IQ-matched typically developing children on two aspects of EF: flexibility (Dimensional Change Card Sort; DCCS) and verbal working memory (backward digit span). These tasks are appropriate for 6–7 year olds with established criteria for passing (Carlson, 2005; Cohen, 1997; Zelazo, 2006) and provide additional information about the uniformity of early EF deficits in ASD. We predicted less flexibility while switching rules during the DCCS task based on prior work with young children with ASD and intellectual impairment and older children with ASD without intellectual impairment (e.g., Colvert, Custance, & Swettenham, 2002; Geurts, Verté, Oosterlaan, Roeyers, & Sergeant, 2004; Reed et al., 2011; but see Dichter et al., 2010). Given the relatively spared verbal working memory ability among older individuals with ASD (Kenworthy et al., 2008), we anticipated spared performance. Second, if EF impairments were detected in the ASD group, the present study examined whether performance related to social communication functioning as well as social and repetitive symptoms. We predicted EF would relate to social communication functioning, given its relation to theory of mind ability (Pellicano, 2007; 2010). Following the suggestion of Pellicano et al (2006), we explored whether the failure to find a relation between symptoms and EF was a result of narrow measurement of symptoms.

Methods

Sixty 6–7 year olds were recruited to obtain a final matched sample of 23 children with idiopathic autism spectrum disorders and 20 children with typical development. Exclusionary criteria for both groups included medical disorders or injuries involving the central nervous system, major physical abnormalities, seizures, and significant sensory or motor impairments. In addition, typically developing children were excluded if they had a family history of ASD, birth or developmental abnormalities, learning or language disability, current or past history of psychiatric or neurological disorders, or regularly used psychoactive medication. The study was conducted in accordance with the university Human Subjects Division.

Groups were matched on age, sex, and intelligence (see Table 1). All children had General Conceptual Ability (GCA) scores above 80 on the school age core of the Differential Ability Scales-2 (DAS-2; Elliott, 1990). Biological parents were well educated and the sample was predominantly white; groups did not differ on these characteristics or on household income. For children with ASD, a previous diagnosis was required and confirmed with the Autism Diagnostic Interview-Revised (ADI-R; Rutter, Le Couteur, & Lord, 2003) and Autism Diagnostic Observation Schedule (ADOS; Lord, Rutter, DiLavore, & Risi, 2002; Gotham, Risi, Pickles, & Lord, 2007) per DSM-IV-TR criteria (American Psychiatric Association, 2000).

Executive function was measured via the Dimensional Change Card Sort (DCCS; Diamond, Carlson, & Beck, 2005; Zelazo, 2006) and the backward portion of the Children's Memory Scale Numbers subtest (Cohen, 1997). DCCS cards varied on three dimensions: color, shape, and the presence of a black star. Directions for sorting were repeated and dimensions were labeled for each card as it was presented (e.g., "*If it's blue, then put it here, but if it's red, put it there. Here is a blue/red one.*"). Cards were sorted without feedback into two opaque boxes labeled by cards with the same shapes and colors as the sorting cards but in the opposite combination. That is, the box labels only matched on one dimension—color or shape. In the first, pre-switch phase, children sorted by color or shape, which was counterbalanced across participants. Next, in the post-switch phase the sorting dimension was switched. The passing criterion for these phases was five correct sorts on six consecutive trials. Then, during the mixed sorting phase, the presence or absence of a star indicated whether the color or shape rule was to be followed. Stars appeared on 6 of 12 cards. At least nine correct sorts were required to pass the mixed phase. The dependent variable was the number of phases passed (Zelazo, 2006). During Numbers Backward, children repeated strings of numbers in reverse order. Two items of each span length were administered until two consecutive spans were missed. Each correct span was awarded one point and the dependent variable was the total number of points (i.e., raw score).

Both symptoms and functioning were assessed (see Table 1). Although there may be overlap in social communication symptoms and function, the scope of these measures differs. A social communication functioning composite was created by averaging the Social Skills Rating System (SSRS; Gresham & Elliott, 1990) and the Vineland-2 (Sparrow, Cicchetti, & Balla, 2005) Socialization and Communication scores, Cronbach's $\alpha = .85$. These scales measure broad social and communication behaviors including following directions, reading, writing, manners, sportsmanship and personal responsibility. Current clinician-observed ASD symptoms were measured via the ADOS Social Affect and Restricted/Repetitive Behaviors scales. Parent report of current repetitive symptoms was obtained via the Repetitive Behavior Scale-Revised (RBS-R; Bodfish, Symons, & Lewis, 1999) and of lifetime higher-order repetitive behaviors via the ADI-R algorithm C1 and C2 (circumscribed interests, compulsive behaviors and rituals). The ADOS, RBS-R and ADI-R are ASD-specific measures and closely linked with symptoms of ASD.

For each measure, groups were first compared. For DCCS phases passed, data were ordinal, so Mann-Whitney U scores were computed. A t-test was computed for Numbers Backward. Second, if groups differed for the DCCS, the ASD group was subdivided and symptoms and functioning were compared between those who failed or passed all phases. If differences were detected for Numbers Backward, Pearson correlations were computed. The IQ range was large, so the relation between EF and IQ was examined and covaried if related.

Results and Discussion

We first compared the performance of children with ASD relative to the comparison group. On the DCCS, all children passed the pre-switch phase. Two children with ASD failed the post-switch phase, which required switching to a new sorting dimension; the remaining 21 passed along with all comparison children. Children who passed the post-switch phase

continued to the mixed phase (i.e., sorting on two dimensions): 10 children with ASD failed and 11 passed, while 6 comparison children failed and 16 passed. The total DCCS score (i.e., number of phases of passed) significantly differed by group, Mann-Whitney $U = 152$, $p = .03$. Children with ASD passed fewer DCCS phases, which suggests they were less flexible in integrating complex rules for behavior. In contrast, Numbers Backward raw scores did not differ between groups, $t(41) = -1.06$, $p = .30$, $d = -0.38$. This suggests the ability to manipulate information held in working memory was similar for both groups. However, not all aspects of working memory appear spared among young children with ASD including visual working memory (Dawson et al., 1998) and real-world application of working memory to complete tasks and follow instructions over time (Smithson et al., 2013). These results provide support for a non-unitary disruption in EF and spared verbal working memory in ASD, as well as continuity in the pattern of findings between younger and older individuals independent of cognitive impairment. This extends previous investigations of EF in young children with ASD and no intellectual impairment (Pellicano et al., 2006; 2007) by using two novel tasks and demonstrating a differential pattern of impairment between a task that emphasizes flexibility and a task of verbal working memory.

Next, because children with ASD had reduced performance on the DCCS, we examined whether poor performance within this group related to functioning in other domains. We first examined IQ and found it was higher among children with ASD who passed all three DCCS phases, $t(21) = 5.21$, $p < .001$, $d = 2.2$. For this reason, IQ was covaried for all subsequent comparisons. We then examined whether children with ASD who passed all three phases had better social communication function. ANCOVA with GCA covaried indicated the children with ASD who passed all three DCCS phases had better social communication skills above and beyond IQ, $F(1, 20) = 7.22$, $p = .01$, $\eta_p^2 = 0.27$. Finally, we examined whether ASD symptoms differed between children who passed and those who did not. With IQ covaried, no differences were detected for children who passed the three DCCS phases in clinician-observed social symptoms or in clinician-observed or parent reported current or lifetime repetitive behaviors.

This study is limited by a relatively small sample size, which restricted the ability to examine performance on tasks beyond the main dependent variable and may have limited the ability to detect some relations between variables. Our primary goal in recruitment was well-matched groups because age and IQ matching were critical for our goals. In addition, the study used clinician-administered EF tasks, which may underestimate the abilities of children with ASD given that they involve both cognitive and social demands. It is possible that computer tasks may have produced different results. However, while seated across from the child, the same experimenter presented scripted verbal instructions without feedback for both tasks. Differences in performance were detected despite the similarity of social task demands. Finally, it should be noted that the psychometric properties of the scales used to measure social function differed from those used to measure symptoms, which may have contributed to the different relations detected.

Findings suggest that the ability to flexibly follow complex rules is reduced relative to verbal working memory in children with ASD without intellectual disability, and differences in the ability to pass all phases of the DCCS within the ASD group mapped to differing

levels of parent reported social communication functioning above and beyond intelligence. The social communication composite captures broad abilities such as flexibility communicating with and responding to others, sharing, playing cooperatively and coping with social demands – all of which may benefit from the ability to manage complex information. This builds on studies linking DCCS performance with theory of mind in children with ASD and comorbid intellectual disability (Zelazo & Müller, 2002) and performance on different executive tasks with theory of mind in children with ASD without cognitive impairment (Pellicano, 2007; 2010).

In contrast, passing all phases of the DCCS did not distinguish children with ASD on their level of clinician observed social-affective symptoms or on three measures of repetitive behavior. These results replicate Pellicano et al. (2006) who also reported no relation between EF and social or repetitive symptoms, and address an unresolved issue raised by that work. In the previous study, only parent report was used to assess symptoms and the authors suggested that direct observation might be more sensitive for detecting relations between symptoms and EF. The current study suggests that this is not the case. Instead, it provides support for a distinction between broadly-construed social communication function and symptoms that are more specific to ASD, which emphasize non-verbal communication and the ability to make and respond to social interactions in a reliable and coordinated way as well as the presence of preoccupations, repetitive actions, and rituals. Yet, it should be noted that our results are inconsistent with work that found *better* DCCS performance related to *more* ASD symptoms among older individuals (Dichter et al., 2010). More work will be needed to reconcile these results, but the current study lends support for the contribution of flexibility to meaningful individual differences in the ability to function effectively across a range of environments in ASD. Clinically, this study highlights meaningful differences in shifting between task demands relative to remembering complex information as well as the need to assess individual differences in flexibility for treatment planning – particularly for social skills training that often emphasizes complex, rule-based strategies. In addition, the relation of EF abilities to social and communication function raise the possibility that interventions targeting EF may enhance treatment outcomes for young children with ASD by improving function in their environment.

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Table 1

Participant descriptive characteristics with Mean, Standard Deviation, and Range

	ASD	Comparison	Signif.(*t*, *p*)
Sex; Race	18 male; 18 white	15 male; 18 white	
Age in months	82.5 (7.3); 72–94	80.9 (7.6); 73–95	0.69, *ns*
Family gross annual income	104.6 (34.5); 45–190	120.7 (69.5); 35–300	−.97, *ns*
Paternal highest education†	6; 4–7	6; 4–7	202.5, *ns*
Maternal highest education†	6; 4–7	6; 5–7	195.0, *ns*
DAS-2 GCA	102.3 (12.4); 84–133	108.0 (5.3); 100–118	−1.9, *ns*
DAS-2 Verbal Composite	104.1 (14.3); 71–125	108.3 (9.2); 94–123	−1.1, *ns*
Vineland-2 Communication	93.7 (9.2); 78–108	106.3 (5.9); 93–115	−5.3, <.001
Vineland-2 Socialization	81.0 (8.2); 66–96	99.7 (5.0); 91–110	−8.9, <.001
Social Skills Rating System	78.8 (13.6); 56–104	107.6 (10.6); 84–127	−7.5, <.001
ADOS Social Affect	10.6 (3.9); 5–19		
Repetitive Beh. Scale-Revised	23.0 (17.7); 1–65	2.9 (3.0); 0–11	5.0, <.001
ADI-R Higher Order Rep. Beh.	4.0 (2.4); 0–8		
ADOS Restricted/Rep. Beh.	3.6 (1.8); 0–8		

Note: Household income is reported in thousands of US dollars. Parental education is coded as 4= high school, 5=some college, 6=college, 7=graduate school. Standard scores with an average range of 85–115 are reported for the Differential Ability Scales-2 (DAS-2), Vineland-2, and Social Skills Rating System (SSRS). Raw scores are reported for the Repetitive Behavior Scale-Revised (RBS-R), Autism Diagnostic Interview-Revised (ADI-R) and Autism Diagnostic Observation Schedule (ADOS).

† Median score and Mann-Whitney *U* is reported for this ordinal variable.