The role of executive functions in social impairment in Autism Spectrum Disorder

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The role of executive functions in social impairment in Autism Spectrum Disorder

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Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder characterized by socio-communicative impairments. Executive dysfunction may explain some key characteristics of ASD, both social and nonsocial hallmarks. Limited research exists exploring the relations between executive function and social impairment in ASD and few studies have used a comparison control group. Thus, the objective of the present study was to investigate the relations between executive functioning using the Behavioral Rating Inventory of Executive Functioning (BRIEF), social impairment as measured by the Social Responsiveness Scale (SRS), and overall autistic symptomology as measured by the Autism Diagnostic Observation Schedule (ADOS) in children and adolescents with and without ASD. Seventy children and adolescents diagnosed with ASD and 71 typically developing controls were included in this study. Findings showed that behavioral regulation executive processes (i.e., inhibition, shifting, and emotional control) predicted social function in all children. However, metacognitive executive processes (i.e., initiation, working memory, planning, organization, and monitoring) predicted social function only in children with ASD and not in typically developing children. Our findings suggest a distinct metacognitive executive function-social symptom link in ASD that is not present in the typical population. Understanding components of executive functioning that contribute to the autistic symptomology, particularly in the socio-communicative domain, is crucial for developing effective interventions that target key executive processes as well as underlying behavioral symptoms.

Keywords: Autism Spectrum Disorder; Executive function; Social impairment; Metacognition.
Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder characterized by impairments in social interaction and communication as well as restricted interests and repetitive behaviors (American Psychological Association, 2013). The range of functioning and symptom severity accounts for the heterogeneous presentation of ASD. Numerous theories have attempted to account for the autistic symptomology. One well-documented theory is the Executive Dysfunction Theory (see Hill, 2004, for a review), which suggests that the complex behavioral manifestations of ASD are consequences of impaired executive processes.

Executive function is an umbrella term for several mental operations, such as inhibition, set shifting, flexibility, organization, planning, self-monitoring, and working memory (see Akbar, Loomis, & Paul, 2013; Hughes, Russell, & Robbins, 1994). Collectively, these cognitive processes enable an individual to disengage from the immediate context in order to coordinate and execute future goals. Executive function deficits have been implicated in both the social and nonsocial symptoms of ASD. For example, restricted and repetitive behaviors can be attributable to a lack of cognitive flexibility or set-shifting and may also explain rigid and perseverative behaviors (Hill, 2004; Lopez, Lincoln, Ozonoff, & Lai, 2005). Deficits in inhibition, information recall, flexibility, and the ability to monitor, update, and select socially appropriate responses—all aspects of executive functioning—may contribute to the social impairments that characterize ASD (Channon, Charman, Heap, Crawford, & Rios, 2001; Dennis, Agostino, Roncadin, & Levin, 2009; Joseph & Tager-Flusberg, 2004).

While executive dysfunction is widely reported in ASD, there is limited research investigating the link between executive functioning and autistic symptomology. The few existing studies report significant associations between executive functioning and restricted and repetitive behaviors (Kenworthy, Black, Harrison, Della Rosa, & Wallace, 2009; Lopez et al., 2005; South, Ozonoff, & McMahon, 2007). However, with the exception of theory of mind research, less work has been done exploring the relations between executive function and social and communicative symptoms of ASD. Existing studies show that executive functioning is associated with socialization and communication in ASD (Gilotty, Kenworthy, Sirian, Black, & Wagner, 2002; Joseph & Tager-Flusberg, 2004; Kenworthy et al., 2009; McEvoy, Rogers, & Pennington, 1993). However, the majority of studies in the extant literature have used archival clinical data without control groups to confirm that the link between executive function and autistic symptomology is specific to ASD. Further, existing literature heavily relies on laboratory measures for the assessment of executive functions. Such measures sample fractioned executive skills, which may lead to dissociations between behaviors or real-life functioning (Burgess, 1977). The use of informant reports therefore provides a measure of a somewhat different construct of executive functioning from what is assessed by neuropsychological tests but also yields valuable information.

Thus, the present study determined the relation between “every day” (i.e., parent-reported) executive functioning and autistic symptomology, particularly in the social domain, in children and adolescents with and without ASD. Specifically, we used the Autism Diagnostic Observation Schedule (ADOS; Lord et al., 2000; Rutter, DiLavore, Risi, Gotham, & Bishop, 2012) as a measure of overall symptom severity and the Social Responsiveness Scale (SRS; Constantino & Gruber, 2005) as a measure of social function for a more in-depth examination of the executive function-social impairment link. We hypothesized relations between executive functioning measures and social functioning in
children with and without ASD; specifically, ASD symptom severity would be associated with reduced executive functioning.

**METHOD**

Seventy children and adolescents diagnosed with ASD (61 males) and 71 typically developing (54 males) children ages 6–15 years were included in this study. Participants were recruited through community centers, parental support groups, newsletters, hospital flyers, schools, and autism advocacy agencies. Diagnosis of ASD was confirmed with a combination of expert clinical judgment, clinical records, and the ADOS (Lord et al., 2000; Rutter et al., 2012), which was administered by a trained individual who maintains interrater research reliability. Exclusion criteria for all participants included any current significant Axis I psychiatric comorbidities, neurological disorders, acquired brain injury, and uncorrected vision. Use of psychotropic medications was an exclusion factor for controls only. Exclusion criteria were assessed through prescreening interviews. Twenty participants with ASD were on psychotropic medication (e.g., stimulants). All participants had an IQ of ≥ 65, as measured by the Wechsler Abbreviated Scale of Intelligence (WASI; Wechsler, 2002). Participants were age and sex matched (see Table 1 for details). The study was approved by the Hospital for Sick Children Research Ethics Board and informed consent and/or assent were obtained for all participants.

The ADOS (Lord et al., 2000; Rutter et al., 2012) was administered to the clinical sample to assess overall autistic symptomology. The ADOS is a semi-structured standardized interview that assesses autism symptoms in the domains of communication, reciprocal social interaction, restricted interests, repetitive behavior, and imagination and creativity, with higher scores indicative of more autism symptoms. Total ADOS scores ($M = 10.72, SD = 3.43$) fell well above the clinical threshold of 7 for ASD. Total ADOS

<table>
<thead>
<tr>
<th>Variable</th>
<th>ASD (n = 70)</th>
<th>Control (n = 71)</th>
<th>Significance Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demographics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sex</td>
<td>87.1</td>
<td>76.1</td>
<td>$X^2 (1, 141) = 2.88$</td>
</tr>
<tr>
<td>Age</td>
<td>11.23 (2.47)</td>
<td>11.69 (2.70)</td>
<td>$t(139) = 1.06$</td>
</tr>
<tr>
<td>IQ</td>
<td>100.15 (15.54)</td>
<td>110.09 (11.93)</td>
<td>$t(143.6) = 4.04^*$</td>
</tr>
<tr>
<td>Clinical Test Data</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BRI</td>
<td>70.15 (11.88)</td>
<td>45.61 (7.37)</td>
<td>$t(108.6) = 14.27^*$</td>
</tr>
<tr>
<td>MI</td>
<td>66.42 (9.12)</td>
<td>47.62 (8.75)</td>
<td>$t(129) = 12.04^*$</td>
</tr>
<tr>
<td>SRS Total</td>
<td>79.39 (13.00)</td>
<td>45.17 (7.38)</td>
<td>$t(105.1) = 18.67^*$</td>
</tr>
<tr>
<td>ADOS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>10.72 (3.43)</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Severity</td>
<td>6.26 (1.90)</td>
<td>N/A</td>
<td></td>
</tr>
</tbody>
</table>

*Note. BRIEF = Behavioral Rating Inventory of Executive Function; BRI = Behavioral Regulation Index; MI = Metacognition Index; SRS = Social Responsiveness Scale; ADOS = Autism Diagnostic Observation Schedule.*

*p < .001.
scores were also converted into severity scores \((M = 6.26, SD = 1.90;\) Gotham, Pickles, & Lord, 2009). Severity scores facilitate comparability between different versions and modules of the ADOS and serve as an autism severity metric that accounts for age and language proficiency, with a score of 10 being the most severe. ADOS total and severity scores were included as potential outcome variables.

To measure social symptomology, all parents completed the SRS (Constantino & Gruber, 2005), which is a 65-item informant report that assesses interpersonal, communicative, and repetitive behaviors that are typical of individuals with ASD. Responses to items are on a 4-point scale (0 = never true to 3 = almost always true) and assess social awareness, social information processing, capacity for reciprocal social communication, social anxiety or avoidance, and autistic preoccupations and traits. Higher SRS Total scores are indicative of greater social impairment and \(T\)-scores \(\geq 65\) represent clinical symptomology.

Executive function was measured using the Behavior Rating Inventory of Executive Function (BRIEF; Gioia, Isquith, Guy, & Kenworthy, 2000), a parent inventory of executive functioning based on observations within the home environment for children and adolescents with a range of developmental and neurological conditions. The BRIEF has six subscales that are collapsed into two main indices: the Behavioral Regulation Index (BRI), which includes inhibition, shifting, and emotional control, and the Metacognition Index (MI), which includes initiation, working memory, planning/organization, organization of material, and monitoring. \(T\)-scores \(\geq 65\) are indicative of clinically significant symptoms.

All predictor, outcome, and covariate variables were inspected for outliers. Independent samples \(t\)-tests were conducted to explore between-group differences in demographic, cognitive, and clinical data. Pearson correlations were completed to examine the bivariate relations among potential covariates (age, IQ), predictor variables (BRI, MI), and outcome variables (SRS, ADOS severity, ADOS total score) within each group. Based on results of correlations, factors were selected for inclusion in subsequent multiple regression analyses to understand the unique contribution of executive functioning to social and overall autistic symptomology.

Given the clinical context of the study, covariates and executive function variables correlated at \(r \geq .24\) (medium effect size or greater; Cohen, 1977, 1992; see Kenworthy et al., 2009) with ADOS and SRS scores included in subsequent analyses. For each group, separate multiple regression models were calculated with social function (SRS) as the outcome variable and relevant executive function scores (BRI and MI) as predictors, entering all variables simultaneously; ADOS scores were not correlated with any predictor variables at the bivariate level and thus were excluded as outcome measures from subsequent regression analyses. Initial regression models were run to verify that data met the assumption of normally distributed residuals, homogeneity of variance and linearity, and contained approximately normally distributed errors. Data were also assessed for multicollinearity through tolerance and variance inflation factors (VIF) for predictors.

RESULTS AND DISCUSSION

Parents reported greater social impairment in children with ASD \((M = 79.39, SD = 13.00, \text{“severe” clinical range}), than their typically developing peers \((M = 45.17, SD = 7.38, \text{“normal” range}), t(105.17) = 18.67, p < .001. Additionally, parents indicated that children with ASD had more behavioral regulation difficulties \((\text{ASD: } M = 70.15, \text{typical: } M = 60.10, t(104.17) = 13.67, p < .001).
EXECUTIVE FUNCTIONS IN ASD

Table 2 Correlation matrix between potential covariates, executive function and SRS scores for control children.

<table>
<thead>
<tr>
<th>Variables</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. SRS Total</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>2. Age</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
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<td>3. IQ</td>
<td>—</td>
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<td>—</td>
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<tr>
<td>4. BRIEF BRI</td>
<td>—</td>
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<td>—</td>
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<td>—</td>
</tr>
<tr>
<td>5. BRIEF MI</td>
<td>—</td>
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</tbody>
</table>

Note. BRIEF = Behavioral Rating Inventory of Executive Function; BRI = Behavioral Regulation Index; MI = Metacognition Index; SRS = Social Responsiveness Scale.
*p < .05. **p ≤ .001, meets clinical significance of r ≥ .24.

Table 3 Correlation matrix between potential covariates, executive function and autistic symptomology (SRS and ADOS) scores for children with ASD.

<table>
<thead>
<tr>
<th>Variables</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. SRS Total</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
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<tr>
<td>2. Age</td>
<td>—</td>
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<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
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<tr>
<td>3. IQ</td>
<td>—</td>
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<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>4. BRIEF BRI</td>
<td>—</td>
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<td>—</td>
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<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>5. BRIEF MI</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>6. ADOS Severity</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
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<tr>
<td>7. ADOS Total</td>
<td>—</td>
<td>—</td>
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<td>—</td>
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<td>—</td>
</tr>
</tbody>
</table>

Note. BRIEF = Behavioral Rating Inventory of Executive Function; BRI = Behavioral Regulation Index; MI = Metacognition Index; SRS = Social Responsiveness Scale; ADOS = Autism Diagnostic Observation Schedule.
*p < .05. **p ≤ .001, meets clinical significance of r ≥ .24.

SD = 11.88; Controls: M = 45.61, SD = 7.37, t(108.60) = 14.27, p < .001, and metacognitive difficulties (ASD: M = 66.42, SD = 9.12; Controls: M = 47.62, SD = 8.75), t(129) = 12.04, p < .001, than typically developing children. Children with ASD fell within the clinically significant range on both the BRI and MI.

Initial bivariate correlations indicated that, while neither of the potential covariates (i.e., age and IQ) were significantly correlated with outcome measures (ADOS Total, ADOS severity, and SRS Total), the BRIEF BRI and MI scores were significantly positively associated with the SRS Total score in both children with and without ASD (see Tables 2 and 3). The BRIEF BRI and MI were not correlated with ADOS total scores or severity scores, and therefore, regression models predicting ADOS scores were not conducted.

Multiple regression analyses were conducted to identify the unique contribution of executive function (BRI and MI) to social symptoms (SRS Total) in each group. The overall regression models were significant for both children with ASD, R = .67, R² = .45, F(2, 64) = 25.34, p < .001, and typically developing children, R = .62, R² = .38, F(2, 63) = 18.60, p < .001, accounting for 43% and 36% of the adjusted variance in social symptomology, respectively. However, whereas the BRIEF BRI was a unique significant predictor of SRS Total score in both the ASD, β = 0.42, p = .002, and control groups, β = 0.63, p < .001, the BRIEF MI was a significant predictor of SRS Total score in the ASD group only, β = 0.31, p = .02 (see Table 4).
Our findings demonstrate a link between behavioral regulation executive processes (i.e., inhibition, shifting, and emotional control) and social function that was predictive in the typical population and children with ASD. However, the relation between social symptoms and metacognitive executive processes, such as initiation, working memory, planning, organization, and monitoring, was distinct in ASD and not characteristic of the wider population. In other words, stronger metacognitive abilities were associated with fewer autistic social symptoms. Therefore, social symptoms of ASD appear to be associated with a specific set of executive functions (i.e., metacognitive skills) in which impairment has been noted (see Geurts, de Vries, van den Bergh, 2014; Hill, 2004, for reviews), namely the ability to independently generate new ideas or information (Turner, 1999), to hold information “online” in the mind while completing a task (Luna, Doll, Hegedus, Minshew, & Sweeney, 2007), planning/organization (Sumiyoshi, Kawakubo, Suga, Sumiyoshi, & Kasai, 2011), and self-monitoring (Grynszpan et al., 2012; Lombardo, Barnes, Wheelwright, & Baron-Cohen, 2007). The present findings are inconsistent with Kenworthy and colleagues (2009), who found that only the BRI was predictive of communication symptoms and not social symptoms in ASD. This discrepancy may be due to methodological differences, such as their decision to compute an autism composite score from various performance and informant-based measures of autistic symptomology.

Our findings show that metacognitive deficits in addition to behavioral regulation difficulties predict social impairment in ASD. This suggests that children and adolescents with ASD may require more widespread use of executive functions for social abilities relative to the typical population. Neuroimaging studies also provide evidence for different neural activation patterns underlying executive functioning and social processing between ASD and typically developing children (Di Martino et al., 2009; for a review; Just, Cherkassky, Keller, Kana, & Minshew, 2007). Findings may also reflect the possibility that extensive use of executive functioning in typically developing children is not necessary for successful social interactions, which can be managed efficiently using a more focused and refined use of executive processes.

Table 4 Multiple regression analysis of executive function on SRS total scores in children and adolescents with and without ASD.

<table>
<thead>
<tr>
<th>Group</th>
<th>Variable</th>
<th>B</th>
<th>SE B</th>
<th>β</th>
<th>R²</th>
<th>Adjusted R²</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASD</td>
<td>BRI</td>
<td>0.46</td>
<td>0.14</td>
<td>0.42**</td>
<td>0.45</td>
<td>0.43</td>
<td>25.34***</td>
</tr>
<tr>
<td></td>
<td>MI</td>
<td>0.45</td>
<td>0.19</td>
<td>0.31*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Controls</td>
<td>BRI</td>
<td>0.60</td>
<td>0.13</td>
<td>0.63***</td>
<td>0.38</td>
<td>0.36</td>
<td>18.60***</td>
</tr>
<tr>
<td></td>
<td>MI</td>
<td>-0.01</td>
<td>0.11</td>
<td>-0.02</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note. BRIEF = Behavioral Rating Inventory of Executive Function; BRI = Behavioral Regulation Index; MI = Metacognition Index; SRS = Social Responsiveness Scale.

*p < .05. **p < .005. ***p < .001.
(see Hughes & Leekam, 2004 for a review). Moreover, interventions that target metacognitive skills have been shown to improve social abilities in children and adolescents with ASD (Kenworthy et al., 2014) and intellectual disabilities (Rosenthal-Malek & Yoshida, 1994).

There are some limitations of the present study. Although a valid measure of social function, the SRS also includes items pertaining to repetitive behavior and sensory issues. In addition, the present study relied only on parental reports of executive functioning and did not include supplemental laboratory performance measures; future work that combines laboratory and informant-based measures is needed for a more in-depth investigation. Furthermore, the narrow range of SRS scores among the control group may have impacted our ability to detect relations between metacognitive ability and social functioning. Lastly, although our groups were not matched on IQ (lower IQ scores in children with ASD), IQ did not correlate with outcome variables and were not included in regression analyses.

The link between social cognition and executive functioning is a complicated and long-standing discussion that has current implications on whether social impairment may also impact BRIEF scores. While there is a general consensus that executive function and theory of mind are linked, directionality of this relationship is unclear. While evidence exists to suggest that theory of mind is a prerequisite for executive function (Perner, 1998; Perner & Lang, 1999) and vice versa (Russell, 1996, 1997), the general consensus is that early executive functioning predicts theory of mind, at least in younger children (see Austin, Groppe, & Elsner, 2014, for a discussion). Overall, our results provide support that metacognitive executive functioning accounts for the variance in autistic social symptomology and that this link is discrepant from that found in the normative population. Investigating executive function components that contribute to the severity of autistic symptomology, particularly in the socio-communicative domain, provides insight for the development of effective interventions for individuals with ASD.

REFERENCES


