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MORE THAN IQ: EXECUTIVE FUNCTION EXPLAINS ADAPTIVE BEHAVIOR ABOVE AND BEYOND NONVERBAL IQ IN YOUTH WITH AUTISM AND LOWER IQ

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Abstract

Adaptive behavior is a critical metric for measuring outcomes in those with autism spectrum disorder (ASD). Executive function skills predict adaptive behavior in youth with ASD with average or higher IQ; however, no study has examined this relationship in ASD with lower IQ (IQ 75). The current study evaluated whether executive function predicted adaptive behavior in school-age youth with ASD with lower IQ, above and beyond nonverbal IQ. We examined adaptive behavior and executive function through informant report on 100 youth with ASD with lower IQ. Executive function skills explained variance in all adaptive domains, beyond nonverbal IQ; monitoring skills played a significant role. This research suggests that malleable skills like executive function may contribute to functional outcomes in this population.

Keywords

autism spectrum disorder; lower IQ; executive function; adaptive behavior

Less than 20% of all adults with autism spectrum disorder (ASD) live independently and approximately 33% are employed (Anderson, Shattuck, Cooper, Roux & Wagner, 2014; Roux et al., 2013). These statistics likely overestimate the positive outcomes for the one-third of adults with ASD who have a comorbid intellectual disability diagnosis (ASD+ID; Christensen et al., 2016). Individuals with ASD+ID show lower levels of residential independence, daily living skills, and social contacts relative to other groups with equivalent IQ ranges, such as Down syndrome (Esbensen, Bishop, Seltzer, Greenberg & Taylor, 2010). Although adults with Down syndrome and ASD+ID demonstrate similar levels of cognitive ability, those with ASD+ID tend to achieve much poorer functional outcomes than those with Down syndrome. Thus, IQ alone cannot explain this difference and additional skills are likely at play. Adaptive behavior is a strong predictor of higher quality of life and social

inclusion in ASD and, therefore, is an important measure of functional outcome (Bishop-Fitzpatrick et al., 2016; Kirby, 2016; Orsmond, Shattuck, Cooper, Sterzing & Anderson, 2013). Adaptive behavior is a well-measured construct, referring to the capacity to function independently at home and in the community throughout the lifespan (Sparrow, Cicchetti & Saulnier, 2016). Prior research suggests that adaptive behavior tends to plateau in the early-to mid-20s in adults with ASD+ID, while other groups with ID continue to develop these skills (Smith, Maenner & Seltzer, 2012). Thus, there is a need to identify malleable skills that predict positive outcomes for individuals with ASD with lower IQ, above and beyond IQ, and may ultimately serve as viable targets for intervention during childhood.

Adaptive behaviors are complex and call upon multiple cognitive, social, and affective abilities. Listening to a story, for example, requires the ability to sit still, make eye contact, and pay attention for several minutes, among many other skills. However, there is limited knowledge on how such cognitive skills contribute to these higher-level, real world abilities. Executive function has been identified as one set of cognitive processes that predict adaptive behaviors in youth with ASD with average IQ (Gilotty, Kenworthy, Sirian, Black, & Wagner, 2002; Peterson, Noggle, Thompson, & Davis, 2015; Pugliese et al., 2015, 2016). However, to our knowledge, this relationship has not been studied in youth with ASD with lower IQ, so we do not know whether the predictive power of executive function skills extends into this end of the cognitive spectrum.

Executive function refers to a set of cognitive processes that regulates thoughts, emotions, and actions and channels them into socially appropriate, goal-directed behavior (Miller & Cohen, 2001; Zelazo, Carlson, & Keske, 2008). One well-validated caregiver-report measure of executive function used commonly in the ASD literature detailed below is the Behavior Rating Inventory of Executive Function (BRIEF). The BRIEF is organized into two major indices: Metacognition (MCI), the control of thought, and Behavior Regulation (BRI), the control of actions and emotions. The eight BRIEF scales are based upon executive subdomains that include the “abilities to initiate and sustain behavior, inhibit competing actions or stimuli, select relevant task goals, plan and organize problem-solving strategies, shift strategies flexibly when necessary, and monitor and evaluate one’s own behavior, [as well as] retaining information actively in working memory in the service of problem-solving” (Gioia et al., 2002). Parent rating scales including the BRIEF, despite a weak relationship to performance-based measures of executive function, have a history of linking to important real-world outcomes and biological variables (Isquith, Roth, & Gioia, 2013). Parent reports are particularly valuable because they offer complementary information by tapping into trait characteristics, as parents are asked to average behavior over an extended period of time. In most studies on executive function and adaptive behavior in individuals with ASD with average or higher IQ, adaptive behavior was measured by parent report on the Vineland Adaptive Behavior Scales, which includes Communication, Daily Living Skills, and Socialization Domains, or the Adaptive Behavior Assessment System-II (ABAS-II), which includes domains of Communication, Community Use, Functional Academics, Home Living, Health and Safety, Leisure, Self-Care, Self-Direction, Social, and Work.

The literature on executive function and adaptive behavior in individuals with ASD is variable, but it tends to point to an important relationship between executive function and

adaptive behavior in this population. Gilotty and colleagues (2002) found that parent-reported initiation and working memory skills were correlated with parent-reported adaptive socialization and communication skills. Peterson and colleagues (2015) found that metacognition, behavior regulation, initiation, and global executive skills were significantly correlated with all ABAS-II domains. Shifting, working memory, and planning and organizing were also correlated with most ABAS-II domains. Pugliese and colleagues (2015) explored the relationship between executive function and adaptive skills above and beyond IQ. They found that stronger parent-reported working memory and initiation skills predicted better adaptive communication skills, and that stronger initiation and shifting skills predicted better adaptive socialization skills. They also found that better initiation, working memory, and organization of materials predicted better daily living skills. In their longitudinal study using a subset of that sample, Pugliese and colleagues (2016) suggested the importance of monitoring, inhibition, and shifting in predicting later adaptive outcomes, with self-monitoring robustly predicting later scores in all VABS domains. To our knowledge, only one study of executive function and adaptive behavior in ASD includes an ASD+ID group (Panerai, Tasca, Ferri, D-Arrigo, & Elia, 2014), but this includes only 16 children with ASD and either borderline intellectual functioning or mild intellectual disability. Additionally, when correlating executive function measures with VABS, they collapsed all children with ASD into one group regardless of cognitive level. This study found no significant correlation between BRIEF and VABS in any group, but this study looked only at overall BRIEF scores (i.e. Global Executive Composite score) in relation to overall VABS, rather than individual skills. They did find significant correlations between several performance-based executive function tasks (including measures of mental flexibility, response inhibition, and generativity) and parent-reported adaptive behavior on the VABS. However, this included the full ASD group (without regard to cognitive ability) and these relationships were not significantly different from those found in their typically-developing control group. Interestingly, in several of these studies (i.e. Pugliese et al., 2015, 2016; Rosenthal et al., 2013), age was a negative predictor of adaptive behavior in ASD with average or higher IQ, indicating that there may be a widening gap between adaptive behavior and IQ with age. Less is known about whether these relationships extend across the cognitive spectrum to individuals with ASD with lower IQ.

The current study is a secondary analysis of cross-sectional, archival data. We utilize parent report as a first step toward understanding how executive function contributes to adaptive behavior in youth with ASD with lower IQ, above and beyond the role of IQ. In response to previous research, which focuses on ASD with average or higher IQ or ASD more broadly, the current study focuses specifically on youth with ASD with lower IQ (IQ ≤ 75). This IQ range was selected because some children with ASD may have a lower IQ and experience moderate difficulties, but not meet traditional ID diagnostic criteria. This approach is consistent with a Research Domain Criteria framework put forward by the National Institute of Mental Health to examine neurodevelopmental and psychiatric conditions along a continuum rather than adhering to traditional diagnostic boundaries (Sanislow et al., 2010). In line with prior literature in ASD with average or higher IQ, we hypothesize that fewer difficulties with executive function skills will predict better adaptive behavior in this sample. Given the variety of executive function skills implicated in prior work, we will examine all

BRIEF scales in our analyses, to determine which scales stand out as significant predictors of adaptive behavior in this ASD with lower IQ sample. IQ has a significant relationship with adaptive behaviors (Kenworthy, Case, Harms, Martin, & Wallace, 2009; Klin et al., 2007; Saulnier & Klin, 2007). Therefore, we will test the contributions of these executive skills above and beyond those of nonverbal IQ, as nonverbal IQ assesses cognitive skills without the potential confound of a child's language disorder (DeThorne & Schaefer, 2004). Because prior studies in ASD have reported changes in standardized scores of parent-reported adaptive behavior and executive function across age (Pugliese et al., 2015, 2016; Rosenthal et al., 2013), we hypothesize that age will also be a negative predictor of adaptive behavior in our sample. Therefore, we also included age as a covariate in our regression models.

Methods

Participants

As this study is a secondary analysis, participants were pulled from a database of all participants seen at the Center for Autism Research at the Children's Hospital of Philadelphia across several studies and their data were included in this manuscript only if they met our study's inclusion criteria. Our final sample included 100 youth with ASD (91 males; age = 6–17 years, $M = 10.17$, $SD = 2.94$; 69% Caucasian; 21% Black; 3% Asian; 1% Biracial; 6% Other or Race Not Specified; 13% Hispanic ethnicity). Inclusion criteria were: complete BRIEF Parent Form; complete Vineland-II Caregiver Report; Full-Scale IQ ≥ 75 , as determined by the General Conceptual Ability score on the Differential Abilities Scale, 2nd Edition (DAS-II; Elliott, 2007) or the Full-Scale score on the Wechsler Intelligence Scale for Children (WISC-IV; Wechsler et al., 2003); and a *DSM-IV-TR* diagnosis of autistic disorder, Asperger's disorder, or pervasive developmental disorder – not otherwise specified (APA, 2000) based on expert clinical opinion. Expert clinical judgment was informed by revised algorithm scores from the Autism Diagnostic Observation Schedule (ADOS; Lord, Rutter, DiLavore, & Risi, 1999), the Social Communication Questionnaire (SCQ; Rutter, Bailey, & Lord, 2003), and/or the Autism Diagnostic Interview – Revised (ADI-R; Rutter, Le Couteur, & Lord, 2003). Because these data were collected prior to the release of the ADOS-2, the decision to score the ADOS using a revised algorithm is based on prior work showing increased specificity and improved predictive value in classification of ASD with this algorithm (Gotham et al., 2007). The revised algorithm is comparable to DSM-5 and ADOS-2 conceptualizations of ASD because it has two symptom domains ("Social Affect" and "Restricted, Repetitive Behaviors"). This algorithm sums the two domains to create one total score; the diagnostic thresholds are then applied to this overall score. The decision to include children with a full-scale IQ ≥ 75 allows for the broadest possible range of IQ profiles within this subset of the ASD population; therefore, some children may have close to average IQ in one domain, but substantially lower in another (Nowell et al., 2015). All participants' data were collected at the (<removed for blindness>) between 2009 and 2014.

Measures

Adaptive behavior was measured with the Vineland Adaptive Behavior Scales, Second Edition – Parent/Caregiver Rating Form (VABS-II; Sparrow, Cicchetti, & Balla, 2005), where Communication, Daily Living Skills, and Socialization domain Standard Scores ($M = 100$; $SD = 15$) served as the key dependent variables. Lower standard scores on the VABS-II indicate lower levels of adaptive behavior; a score of 71–85 falls in the “moderately low range” and a score of 70 or lower is considered to be in the “low range”, relative to same-aged individuals.

Executive Function was assessed by the Behavior Rating Inventory of Executive Function - Parent Form (BRIEF; Gioia, Isquith, Guy, & Kenworthy, 2000). The BRIEF consists of three scales, including skills such as adjusting to changes in routine (Shift), suppressing impulsive responses (Inhibit), and moderating one's emotions (Emotional Control). The MCI consists of five scales that assess skills such as being a self-starter (Initiate), following multi-step directions (Working Memory), organizing problem-solving approaches (Plan/Organize), keeping work and play spaces in order (Organization of Materials), and knowing how one's actions affect others or whether one is on task (Monitor). Higher T-scores ($M = 50$, $SD = 10$) are associated with greater difficulties in executive function; a score of 65 or higher suggests an area of possible concern. In our analyses, we focus on the T-scores from all eight BRIEF scales.

IQ was assessed using the DAS-II. The DAS-II yields Verbal Ability, Nonverbal Reasoning Ability, and Spatial Ability scores, which collectively inform a General Conceptual Ability score. A subset of two children participated in a study that used the WISC-IV instead of the DAS-II. WISC-IV scores include Verbal Comprehension, Perceptual Reasoning, Working Memory, and Processing Speed, which together yield a Full-Scale score. In the current study, non-verbal IQ is explored as a covariate; “nonverbal IQ” throughout refers to Nonverbal Reasoning Ability on the DAS-II or Perceptual Reasoning on the WISC-IV. Both assessments report standard scores ($M = 100$, $SD = 15$).

Social communication symptoms, introduced in our exploratory analyses, were assessed with the parent-report Social Responsiveness Scale (SRS; Constantino & Gruber, 2005). The SRS contains 65 items addressing social impairments related to ASD. Its scales include social awareness, social information processing, reciprocal social communication, social motivation, and autistic mannerisms. Because all items from the original SRS are identical to those on the SRS-2 School-Age Form (Constantino & Gruber, 2013) and all participants fell within the School-Age Form age range (4–18 years), we re-scored the SRS using the corresponding SRS-2 algorithms and norms. To assess social communication symptoms specifically, we focused on a subset of items from the SRS-2 Social Communication and Interaction scale (i.e. all subscales except for autistic mannerisms). Prior literature has suggested roughly 15 items on the SRS(–2) that are specific to ASD (Reiersen et al., 2007 & 2008). Of those, five address RRBI or sensory sensitivities and three are identical in content to items on the VABS-II, our primary outcome measure (see Table 1). We created a sum of the remaining 7 items' raw scores to attain a measure of social communication related ASD symptoms on the SRS-2 (hereinafter, “ASD Social Communication Symptoms”). This score ranges from 0 to 21, with a higher score indicating greater impairment (i.e. higher level of

ASD symptomatology). We also report mean SCI t-scores in Table 2 to supply traditional standardized scores for reference. Higher T-scores indicate more social and communication difficulties associated with ASD. On the SRS-2, scores of 60–65 are considered mildly impairing, scores of 66–75 are moderately impairing, and scores of 76 and higher are severely impairing.

Procedures

This study was a secondary data analysis of archival data from several studies at (<removed for blindness>), all of which were approved by the Institutional Review Board at (<removed for blindness>). Consent was obtained from all parents or legal guardians and assent was obtained from children, where possible, prior to participation in these studies. All measures were completed within twelve months of our primary outcome measure (VABS-II). If participants took part in a prior study within one year, ADOS and IQ testing were not repeated. In one case, a participant was included in our analyses based on a community diagnosis of ASD at the time of completion of our measures of interest, because the child was unable to complete an ADOS at the time of their visit; however, this participant completed another study at our center at a later date and clinicians confirmed an ASD diagnosis that was informed by an ADOS-2. All predictor variables were also collected within one year of the VABS-II. All BRIEF administrations were collected within 10 days ($M = 0.64$ days) from VABS-II. All SRS administrations were dated within 170 days ($M = 13.45$ days) from the VABS-II.

A Priori Statistical Analysis Plan

The statistical analysis plan for the current study was inspired by the analyses from Pugliese and colleagues' cross-sectional work (2015), as we hoped to assess the unique variance in adaptive skills that can be explained by executive function above and beyond the influence of IQ. Even though the BRIEF and VABS both take age into account, Pugliese and colleagues (2014) found a strong negative effect of age in predicting adaptive skill level, despite this norming. Similarly, Rosenthal and colleagues (2013) found a negative relationship between age and subscale T-scores on the BRIEF. Therefore, omitting age as a covariate may result in age-related variance that is specific to ASD being attributed inaccurately to differences in executive function skills. Therefore, we include age alongside nonverbal IQ as covariates in our models. To examine the role of executive function in predicting adaptive behavior, we conducted stepwise linear regressions using the "Enter" method. Both models were conducted three times, once with each VABS-II domain serving as the dependent variable. In Model 1, age and nonverbal IQ were entered to determine the amount of variance in each adaptive behavior domain that was explained by the covariates alone. In Model 2, the aforementioned covariates and the t-scores from all eight of the individual BRIEF scales were entered together as variables of interest. To determine the unique variance contributed by the BRIEF scales collectively, model comparisons were conducted between Models 1 and 2, to generate an F Change (F) value, an associated p-value for F , and an R^2 change (R^2) value. This analysis was then repeated for each of the remaining VABS-II domains. All analyses were carried out in R, using the statistical packages psych, stats, glm, and lmsupport (RStudio Team, 2015). Because model

comparisons are based on multiple R^2 values, we refer to multiple R^2 when reporting the explained variance in our results.

Results

Descriptive Statistics

Descriptive statistics of executive function and adaptive behavior measures are presented in Table 2. For raters who indicated their relationship to the child, 78.5% of BRIEF administrations were completed by mother, 9.7% were completed by father, and 11.8% were completed by a parent but did not specify mother or father. For Vineland, 89.1% were filled out by mother and 10.9% by father. For 85.4% of cases, the rater was the same across BRIEF and VABS-II.

IQ, Executive Function, and Social Communication Symptoms with Adaptive Behavior

Bivariate correlations are presented in Table 3, between nonverbal IQ, BRIEF scales, and VABS-II domains. This matrix also includes the SRS-2 SCI and ASD Social Communication Symptoms sum, which are relevant to our exploratory analyses. Correlations between predictor variables and adaptive behavior were weak to moderate in all domains. Specifically, BRIEF Monitor and SRS-2 SCI and ASD Social Communication Symptoms were significantly correlated with VABS-II Communication. BRIEF Initiate and Monitor, as well as SRS-2 SCI, were significantly correlated with VABS-II Daily Living Skills. BRIEF Inhibit, Shift, Emotional Control, Initiate, and Monitor were significantly correlated with VABS-II Socialization, as were and SRS-2 SCI and ASD Social Communication Symptoms.

Communication Domain

Age was a significant negative predictor and nonverbal IQ was a significant positive predictor of Communication scores. Together, these covariates accounted for 32.3% of variance ($F_{2,96} = 22.92$, $p < 0.001$; see Table 4 for regression results). When the eight BRIEF scales were added to this model, they accounted for an additional 9.3% of variance ($F_{8,88} = 1.75$, $p < 0.1$), but only the Monitor scale was significant ($p < 0.05$). Better executive function skills, reflected in higher scores on the Monitor scale, were significant predictors of higher VABS-II Communication scores.

Daily Living Skills Domain

Age was a negative predictor and nonverbal IQ was a positive predictor of Daily Living Skills scores, accounting for approximately 20.8% of variance ($F_{2,96} = 12.57$, $p < 0.001$). When all BRIEF scales were added to the model, the scales collectively accounted for an additional 9.5% of variance, although the model comparison did not reach statistical significance ($F_{8,88} = 1.49$, $p = 0.17$) and no individual BRIEF scale reached statistical significance.

Socialization Domain

In this model, age was a negative predictor and nonverbal IQ was a positive predictor of Socialization scores, accounting for approximately 14.6% of variance ($F_{2,97} = 8.31, p < 0.001$). BRIEF scales predicted an added 18.3% of variance ($F_{8,89} = 3.04, p < 0.01$), but only the Monitor scale was marginally statistically significant ($p = 0.07$). Better scores on the BRIEF, specifically on the Monitor scale, predicted higher VABS-II Socialization scores.

Exploratory Analysis

Because some items on the BRIEF Monitor Scale address monitoring one's own behavior in social settings (e.g., "Does not notice when his/her behavior causes negative reactions" or "Does not realize that certain actions bother others"), we wanted to be confident that this variance in Socialization or Communication Scores on the VABS-II could not be explained instead by social communication symptoms of ASD. To explore this, we focused on the ASD Social Communication Symptoms from the SRS-2. In this analysis, the Communication Domain Standard Score from the VABS-II was regressed onto age, nonverbal IQ, Monitor Scale from the BRIEF, and the ASD Social Communication Symptoms sum from the SRS-2. This was then repeated for the VABS-II Socialization Domain Standard Score.

SRS-2 mean scores are presented in Table 2. When VABS-II Communication Domain Standard Score was regressed on age, IQ, ASD Social Communication Symptoms sum from the SRS-2, and BRIEF Monitor, we found that ASD Social Communication Symptoms and BRIEF Monitor contributed a combined 12.5% of variance. The model was significant ($F_{2,94} = 10.67, associated p < 0.001$), although the statistical significance of Monitor became weaker, trending toward significance ($p = 0.10$), and ASD Social Communication Symptoms were statistically significant ($p < 0.01$). When VABS-II Socialization Domain Standard Score was regressed on the same set of predictor variables, ASD Social Communication Symptoms and Monitor contributed a combined 20.6% of variance. Again, the model was significant ($F_{2,95} = 15.10, associated p < 0.001$) and both Monitor ($p < 0.05$) and Social Communication Symptoms ($p < 0.01$) reached statistical significance. See Table 4 for complete regression results.

Discussion

The goal of this study was to evaluate whether executive function skills predict adaptive behavior in individuals with ASD with lower IQ, above and beyond the role of nonverbal IQ. As expected, older age and lower nonverbal IQ were significant predictors of lower levels of adaptive behavior. We also found that fewer difficulties with executive function predicted better adaptive behavior in this sample, above and beyond age and nonverbal IQ. Difficulty with monitoring one's on-task behavior and/or the effects of their behaviors on others stood out as a specific executive function skill predicting better communication and socialization skills.

The current study demonstrated that better executive function skills predicted better adaptive behavior in children with ASD with lower IQ, extending findings from previous work in

ASD with average or higher IQ (Gilotty, et al., 2002; Peterson, et al., 2015; Pugliese et al., 2015, 2016). In the current study, difficulty monitoring one's behavior was a significant predictor of adaptive communication and marginally significant for socialization skills in our sample of children with ASD with lower IQ. Monitoring skills were also predictive of adaptive behavior in Pugliese and colleagues' longitudinal study (2016). Although Monitor was only marginally significant for adaptive socialization skills in our study, the effect size (change in R^2) was comparable to those in the sample with ASD with average or higher IQ, so our smaller sample size may help to explain why our finding was only marginally significant. Although significant findings with the Monitor scale were demonstrated in Pugliese and colleagues' longitudinal study, their cross-sectional and longitudinal study both pointed to the importance of additional executive function skills, including working memory, initiation, shifting, and organization of materials. In their cross-sectional analysis, Pugliese et al. compare executive function at one time point to adaptive behavior at the same time point. In their longitudinal paper, they compare executive function at one time point to adaptive behavior at the following time point. They find shifting significant in both studies, but differences between studies in the relationship of other specific executive function skills to adaptive behavior. It could be, therefore, that skills like initiation, working memory, and organization of materials are most important for explaining current levels of adaptive behavior in ASD with average or higher IQ, but that skills like monitoring and inhibition become more important for predicting development of adaptive skills, as reflected in later levels of adaptive skills. For children with ASD with lower IQ, the profile of executive function skills that explains concurrent adaptive behavior skills may differ from the profile of those with average or higher IQ; however, it is also possible that our study did not find significant relationships for some of these skills again due to our relatively smaller sample size (100 vs. ~450 in Pugliese et al., 2015). Executive function skill levels based on parent rating in this ASD with lower IQ sample were similar to those in Pugliese and colleagues' sample (2015), so this discrepancy is not due to substantial differences in executive function skills at the group level. Rather, given the large role that nonverbal IQ plays in predicting adaptive behavior in our study, perhaps the more specific skills that predict adaptive behavior may differ in a group with lower IQ.

Given the potential overlap between social items on BRIEF Monitor and social communication symptoms of ASD, we explored whether this variance could be better explained by social communication symptoms. Klin and colleagues (2007) explored the relationship between communicative and social ability and disability in a sample of individuals with ASD and average or higher IQ. Ability was defined as adaptive social and communication skills that allow a person to have successful communication, social interactions, and relationships in everyday life (i.e. per the VABS). Disability referred to deficits in social cognition that are symptomatic of ASD, such as difficulty sharing enjoyment, experiencing empathy, and demonstrating theory of mind (i.e. per the ADOS). Klin and colleagues (2007) found strong correlations among scales within each measure, but very modest correlations between the ADOS and VABS scales, suggesting that ability and disability are independent but related constructs. This varies from the more intuitive conception that fewer ASD symptoms and higher adaptive skills should go hand-in-hand. While Klin and colleagues (2007) found small but significant correlations between social

and communication ability and disability in this sample, a follow-up study including only a subset of this sample without ID (Saulnier & Klin, 2007) did not find a significant correlation between the two. However, neither study estimated this relationship in a sample that included only individuals with ASD and lower IQ.

Our analyses with the SRS follow a similar idea, and we found that the SRS and VABS-II scores are much more highly correlated than the relationship between ADOS and VABS reported previously (see Table 3). The unusually strong relationship between the SRS and VABS-II is concerning from the perspective of attempting to measure social ability (VABS-II) and social disability (SRS-2) as discrete constructs. Furthermore, overlap at the individual item-level is remarkably high. To address this concern, we attempted to use SRS-2 items addressing social communication symptoms of ASD that were not identical between the two measures. However, they were still addressing very similar concepts, as reflected in strong intra-item correlations reported in the SRS-2 and VABS-II manuals (Constantino & Gruber, 2013; Sparrow et al., 2005). With ASD Social Communication Symptoms from the SRS-2 added to the regression models, the relationship between BRIEF Monitor and VABS-II Communication was marginally significant and the relationship between BRIEF Monitor and VABS-II Socialization remained significant. Despite our efforts to separate these social communication constructs between the SRS-2 and VABS-II, their items are likely still very related in content and often completed by the same rater, potentially leading to an inflated relationship. Additionally, at face value, it seems particularly difficult to ask informants to parse lower level social cognition or social communication skills from adaptive social or communication skills with questionnaires. However, the modest effect of BRIEF Monitor even after the SRS-2 symptoms are added suggests that monitoring skills may still play a crucial role in explaining adaptive behavior in this segment of the ASD population. The second edition of the BRIEF (Gioia, Isquith, Guy, and Kenworthy, 2015) has now established that the original Monitor scale is better captured as two distinct subdomains – self-monitoring and task-monitoring; items have been updated in the BRIEF's second edition to better capture these two distinct subdomains. We postulate that task-monitoring skills may be more independent from social communication symptoms of ASD than self-monitoring skills. These questions of the role of lower level social cognition and communication skills and monitoring subdomains in adaptive behavior cannot be well-addressed through the measures available in this study. Future studies using performance-based measures that can better isolate (or minimize) the influence of social skills on executive function and vice versa may obtain better estimates of these lower-level skills that can influence adaptive behavior.

There are several limitations that should be considered when interpreting the results of the current study and may be important in directing future research. One such limitation is that we had a small sample size, relative to the larger cross-sectional study in children with ASD with average or higher IQ (Pugliese et al., 2015). However, the current study was the first to our knowledge to explore this relationship in an exclusively ASD with lower IQ sample and the results provide a few interesting new leads to pursue in future research. For example, future studies can confirm if these findings extend to a sample that exclusively meets diagnostic criteria for an ID diagnosis, and whether the small percentage of our sample that had adaptive behavior ratings in the unimpaired range result from a specific form of

intervention that was particularly beneficial for these individuals, or a bias in adaptive behavior ratings. Additionally, the current study was a secondary analysis of an existing dataset. Therefore, the assessments were not selected with this research question in mind and we were limited to utilizing the existing measures. In the case of this dataset, those measures were based only on informant report. Parent report is an indirect measure of executive function or adaptive behavior and the real-life skills that raters can readily observe are often multiply determined, making it difficult to disentangle specific skills. Additionally, the same parent is often completing both forms, leading to a possibly inflated correlation because of both method overlap and rater bias, rather than reflecting the real association between executive function and adaptive skills. Ideally, a future study should consider using multi-method test batteries to capture executive function processes and other malleable skills such as social communication. A combination of traditional lab-based measures, ecologically valid performance-based measures, and informant report will better capture both basic information processing and real-world functioning. This multi-method approach would also allow the use of latent factor models to obtain more robust measures of each construct (see Miyake et al., 2000; Miyake & Friedman, 2012 for examples in executive function research). Additionally, the cross-sectional design of the current study limits our ability to evaluate the effects of developmental changes in executive function skills and their effects on adaptive outcomes. This is particularly important for individuals with ASD+ID, as their adaptive behavior levels appear to plateau in the early- to mid-20s (Smith, Maenner & Seltzer, 2012), while other groups with similarly low IQ continue to develop their adaptive behavior skills. Thus, longitudinal research from childhood through the transition period to adulthood for people with ASD and lower IQ would be highly informative regarding the role of executive function and other skills (such as social cognition and communication) in predicting adaptive behavior skills at the individual level. Future research should also examine individual differences within the subset of the ASD population with lower IQ. It would be important, for example, to distinguish between those who utilize at least phrase speech (or alternative communicative methods) to spontaneously communicate versus those who are minimally verbal, as language skills may interact with their executive function profiles.

While future research is necessary to address these considerations, the current study provides a first glance into understanding the importance of executive function skills and adaptive behavior in this segment of the ASD population. Executive function may be one of several skills that play into the functional outcomes of people with ASD with lower IQ. The implications of these results are important because executive function is one malleable skill that could possibly be targeted in interventions and supported to influence outcomes. This line of work may eventually lead to either adjusting existing interventions to include executive function training components for those with ASD with lower IQ, or lead to developing new executive function interventions in order to improve functional outcomes such as adaptive behavior. There is growing evidence of potentially efficacious executive function interventions for those with ASD with average or higher IQ (Kenworthy et al., 2013; Wallace et al., 2016), and these interventions may serve as a starting point for those with ASD with lower IQ.

The present study utilized informant-report measures as a first step toward understanding the role of executive function skills in adaptive behavior in youth with ASD with lower IQ. To

our knowledge, this study is the first to test this relationship exclusively in youth with ASD with lower IQ, thereby extending prior work and setting the stage for future research on the implications of executive function and other skills for functional outcomes in the ASD with lower IQ population. More extensive research on such relationships may help to identify distinct profiles of executive and non-executive skills across the cognitive spectrum that may better predict adaptive behavior level. If future longitudinal research supports and extends the relationships suggested in the current study, then this line of research will move the field forward by fostering the development of new executive function interventions for people with ASD with lower IQ, which may be a promising direction for ultimately improving their adaptive behavior outcomes.

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Table 1**SRS-2 Item Inclusion: ASD Social Communication Symptoms**

SRS-2 Item	Excluded	Reason for Excluding
6. Would rather be alone than with others.		
10. Takes things too literally and doesn't get the real meaning of a conversation.	X	Identical to Vineland Communication – Listening and Understanding #18
15. Is able to understand the meaning of other people's tone of voice and facial expressions.	X	Identical to Vineland Social Skills and Relationships – Relating to Others #35
16. Avoids eye contact or has unusual eye contact.		
18. Has difficulty making friends, even when trying his or her best.		
20. Shows unusual sensory interests (e.g., mouthing or spinning objects) or strange ways of playing with toys	X	Item addresses Sensory or RRB
24. Has more difficulty than other children with changes in his or her routine.	X	Item addresses Sensory or RRB
33. Is socially awkward, even when he or she is trying to be polite.		
37. Has difficulty relating to peers.		
39. Has an unusually narrow range of interests.	X	Item addresses Sensory or RRB
42. Seems overly sensitive to sounds, textures, or smells.	X	Item addresses Sensory or RRB
50. Has repetitive, odd behaviors such as hand flapping or rocking.	X	Item addresses Sensory or RRB
51. Has difficulty answering questions directly and ends up talking around the subject.		
53. Talks to people with an unusual tone of voice (e.g., talks like a robot or like he or she is giving a lecture).	X	Identical to Vineland Communication – Talking #41
58. Concentrates too much on parts of things rather than seeing the whole picture. For example, if asked to describe what happened in a story, he or she may talk only about the kind of clothes the characters were wearing.		

Table 2

Descriptive Statistics

Measure	Mean (SD)	Min-Max
BRIEF		
<i>Behavior Regulation Index T-score</i>	67.21 (11.31)	42–97
Inhibit T-score	65.34 (11.78)	40–97
Shift T-score	69.03 (11.54)	43–95
Emotional Control T-score	61.62 (11.09)	37–88
<i>Metacognition Index T-score</i>	64.62 (10.43)	43–84
Initiate T-score	62.70 (9.79)	40–81
Working Memory T-score	67.21 (10.18)	43–87
Plan/Organize T-score	63.32 (12.23)	39–89
Organization of Materials T-score	53.84 (10.78)	33–72
Monitor T-score	64.99 (11.67)	32–86
VABS-II		
Communication Domain Standard Score	69.20 (10.13)	44–95
Daily Living Skills Domain Standard Score	71.08 (12.77)	43–121
Socialization Domain Standard Score	64.91 (12.46)	40–119
SRS-2		
Social Communication and Interaction T-score	76.17 (10.57)	50–101
ASD-Only Social Communication Sum (7 items)	11.74 (4.25)	3–20
IQ		
Nonverbal IQ Standard Score	66.97 (15.43)	24–100
Full-Scale IQ Standard Score	58.34 (12.96)	24–75

Note. $n = 100$ (1 participant missing VABS-II communication and 1 missing Daily Living Skills); BRIEF = Behavior Rating Inventory of Executive Function; SRS-2 = Social Responsiveness Scale, 2nd Edition; VABS-II = Vineland Adaptive Behaviors Scale, 2nd Edition.

Table 3

Bivariate Correlation Matrix

	VABS-II				BRIEF Scales					SRS-2				
	IQ	Com	Soc	DLS	Inhibit	Shift	Emotion	Initiate	Work Mem	Plan/ Org	Org Mat	Monitor	SCI	Soc-Com Symptoms
IQ	1													
VABS Com	0.49	1												
VABS Soc	0.32	0.75	1											
VABS DLS	0.42	0.74	0.79	1										
BRIEF Inhibit	-0.22	-0.23	-0.37	-0.29	1									
BRIEF Shift	-0.08	-0.12	-0.32	-0.15	0.51	1								
BRIEF Emotion	-0.13	-0.12	-0.31	-0.18	0.57	0.66	1							
BRIEF Initiate	-0.21	-0.25	-0.36	-0.33	0.43	0.44	0.34	1						
BRIEF Work Mem	-0.25	-0.24	-0.25	-0.24	0.6	0.41	0.46	0.65	1					
BRIEF Plan/Org	-0.21	-0.22	-0.27	-0.24	0.58	0.45	0.43	0.67	0.68	1				
BRIEF Org Mat	0.03	-0.04	-0.11	-0.05	0.34	0.24	0.22	0.46	0.54	0.55	1			
BRIEF Monitor	-0.28	-0.32	-0.38	-0.3	0.53	0.5	0.46	0.58	0.62	0.69	0.42	1		
SRS-2 SCI	-0.2	-0.36	-0.5	-0.31	0.55	0.53	0.53	0.53	0.56	0.53	0.35	0.56	1	
SRS-2 Soc-Com Symptoms	-0.05	-0.33	-0.4	-0.22	0.46	0.43	0.37	0.45	0.48	0.54	0.41	0.47	0.82	1

Note. Bolded values are significant at $p < 0.01$. BRIEF = Behavior Rating Inventory of Executive Function; Emotion = Emotional Control; IQ = Nonverbal IQ; Work Mem = Working Memory; Plan/Org = Plan/Organize; Org Mat = Organization of Materials; SRS-2 = Social Responsiveness Scale, 2nd Edition; SCI = Social Communication and Interaction T-score; Soc-Com Symptoms = SRS-2 ASD Social Communication Symptoms Sum; VABS-II = Vineland Adaptive Behaviors Scale, 2nd Edition; Com = Communication Domain Standard Score; DLS = Daily Living Skills Domain Standard Score; Soc = Socialization Domain Standard Score.

Table 4
Stepwise Regression Results: VABS-II domains regressed on age, IQ, BRIEF scales, and Social-Communication Symptoms

Predictor	Communication				Daily living skills				Socialization						
	B	SE	B	t	VIF	B	SE	B	t	VIF	B	SE	B	t	VIF
Model 1:															
Nonverbal IQ	0.32	0.05	5.81	***	1.00	0.35	0.07	4.64	***	1.00	0.25	0.08	3.36	**	1.00
Age	-0.97	0.29	-3.36	**	1.00	-0.71	0.39	-1.81	.	1.00	-0.90	0.40	-2.26	*	1.00
Model 2:															
Nonverbal IQ	0.24	0.06	4.08	***	1.23	0.25	0.08	3.06	**	1.23	0.16	0.08	2.06	*	1.20
Age	-1.41	0.32	-4.37	***	1.33	-0.93	0.44	-2.09	*	1.33	-1.00	0.42	-2.37	*	1.33
Inhibit	0.02	0.11	0.22		2.20	-0.13	0.15	-0.92		2.20	-0.18	0.14	-1.30		2.18
Shift	0.10	0.10	0.94		2.09	0.13	0.14	0.93		2.09	-0.03	0.14	-0.22		2.11
Emotional Control	0.02	0.11	0.15		2.08	-0.05	0.15	-0.33		2.08	-0.10	0.14	-0.72		2.09
Initiate	0.03	0.13	0.21		2.40	-0.28	0.18	-1.55		2.40	-0.26	0.17	-1.52		2.40
Working memory	-0.19	0.14	-1.36		3.02	-0.02	0.19	-0.11		3.02	0.11	0.18	0.59		3.02
Org. of materials	0.07	0.10	0.72		1.74	0.11	0.14	0.82		1.74	0.01	0.13	0.11		1.67
Plan/Organize	-0.07	0.12	-0.61		3.17	0.00	0.16	0.01		3.17	0.10	0.16	0.63		3.17
Monitor	-0.22	0.11	-2.02	*	2.36	-0.16	0.15	-1.06		2.36	-0.26	0.14	-1.83	.	2.36
Exploratory Model:															
Nonverbal IQ	0.28	0.05	5.31	***	1.10	--	--	--		--	0.19	0.07	2.67	**	1.10
Age	-1.19	0.27	-4.40	***	1.06	--	--	--		--	-1.25	0.36	-3.48	***	1.06
Monitor	-0.13	0.08	-1.65	*	1.45	--	--	--		--	-0.26	0.11	-2.40	*	1.46
Soc-Com Symptoms	-0.65	0.21	-3.10	**	1.28	--	--	--		--	-0.90	0.28	-3.27	**	1.29

Note. Org. of Materials = Organization of Materials; Soc-Com Symptoms = SRS-2 ASD Social Communication Symptoms Sum;

 $p < 0.001$,

**
 $p < 0.01$,

*
 $p < 0.05$,

.
 $p < 0.1$