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## The Gap between IQ and Adaptive Functioning in Autism Spectrum Disorder: Disentangling Diagnostic and Sex Differences

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### Abstract

Adaptive functioning, or the suite of skills essential for real-world, day-to-day functioning, includes daily living, communication, and socialization abilities. Even in the absence of co-occurring intellectual disability (IQ<70), difficulties in adaptive functioning are prominent in autism spectrum disorder (ASD). Further, cognitively-able ASD individuals demonstrate a gap between IQ and adaptive functioning, which widens with age. Existing studies of IQ-adaptive functioning discrepancies have characterized predominantly male ASD samples; thus, whether the gap is demonstrated in ASD females is unknown. To probe sex- versus diagnosis-specific differences in adaptive functioning in ASD, we characterized adaptive functioning using the Vineland Adaptive Behavior Scales, Second Edition in 177 cognitively-able (IQ>70) ASD (females=75, males=102), and 178 TD (females=87, males=91) youth, aged 8–17 years. We examined whether each group evidenced a gap between full-scale IQ and adaptive skills, and its associations with age. ASD youth evinced significantly lower adaptive skills and a significantly

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greater IQ-adaptive functioning gap than their same-sex TD peers. In this cross-sectional sample, the increase in the IQ-adaptive functioning gap with age was of similar magnitude for ASD males and females, but only reached statistical significance in males. We discuss unique implications the profound IQ-socialization skills gap in particular may have for ASD females.

## Keywords

adaptive functioning; autism; sex differences; IQ

Adaptive functioning encompasses those skills essential for real-world, everyday functioning that generally fall within the broad areas of daily living skills (e.g., self-care), socialization (e.g., interpersonal skills), and communication (e.g., the ability to convey your wants and needs). Deficits in adaptive functioning are a foundational criterion for a diagnosis of intellectual disability (ID), along with an intellectual impairment (e.g., IQ<70). In general, co-occurrence of ID in autism spectrum disorder (ASD) is a predictor of poorer prognosis (Matson & Shoemaker, 2009), and a childhood IQ<70 is associated with poorer adult outcomes (Howlin et al., 2013). More narrowly, among individuals diagnosed with ASD and ID, lower IQ is associated with poorer adaptive functioning (Kanne et al., 2011; Matson & Shoemaker, 2009). In ASD individuals<sup>1</sup> with ID, daily living skills are a relative strength, followed by communication, with the lowest levels of functioning in socialization (Carter et al., 1998; Kraijer, 2000). This autism profile of adaptive skills (i.e., Communication > Daily Living Skills > Socialization) is distinct from what is seen in other ID populations (e.g., Down Syndrome, where socialization is a relative strength and daily living skills are most impaired) (Loveland & Kelley, 1991; Schatz & Hamdan-Allen, 1995; Volkmar et al., 1987).

Studies in ASD individuals with co-occurring ID, suggest low IQ is a key factor in poor adaptive functioning and adult outcomes. However, research indicates that the converse is not true; cognitively-able ASD individuals still display adaptive skills far below what would be expected given their intellectual potential (Bradshaw et al., 2019; Chatham et al., 2018; Klin et al., 2007). Indeed, a profound discrepancy between cognitive ability and adaptive functioning characterizes ASD individuals with IQ>70 (Alvares et al., 2019; Bölte & Poustka, 2002). The profile of adaptive functioning difficulties demonstrated in those with ID is also present in cognitively-able ASD individuals: relative to daily living and communication skills, these individuals show the greatest impairments in socialization, and these difficulties endure throughout the lifespan (Bradshaw et al., 2019; Chatham et al., 2018; Kraper et al., 2017; Pugliese et al., 2015).

The IQ-adaptive functioning gap in ASD without ID begins as early as toddlerhood (Bradshaw et al., 2019), continues through adolescence (Kanne et al., 2011; Klin et al., 2007; Pugliese et al., 2015), and persists into young adulthood (Kraper et al., 2017). Further, the discrepancy widens with age during childhood, adolescence, and young adulthood due to

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<sup>1</sup>We adopt identity-first (e.g., 'autistic individuals'), rather than person-first (e.g., 'individuals with autism') language, consistent with practices and preferences among certain autistic individuals and self-advocate groups (Autistic Adults and other Stakeholders Engage Together (AASET), 2017; Brown, 2011; Kenny et al., 2016; Sequenzia, 2013). We recognize, however, that language preferences and practices may differ among those within the autism community (Vivanti, 2020).

lack of expected age-normative gains in adaptive abilities, but stable IQ scores (Klin et al., 2007; Pugliese et al., 2015), and cognitively-able ASD adults demonstrate levels of independent living, employment, and social connectedness well below what would be expected given their intellectual functioning (Hofvander et al., 2009).

Existing studies of the IQ-adaptive functioning gap have examined exclusively male (Klin et al., 2007) or male-predominant (~71–90% male) (Alvares et al., 2019; Bölte & Poustka, 2002; Bradshaw et al., 2019; Duncan & Bishop, 2015; Kanne et al., 2011; Krapar et al., 2017; Pugliese et al., 2015; Schatz & Hamdan-Allen, 1995) ASD samples; therefore, whether the IQ-adaptive functioning gap that characterizes cognitively-able males also characterizes cognitively-able ASD females is unknown. Females, particularly at the higher ends of the IQ continuum, may present a unique profile of ASD features (Bargiela et al., 2016; Gould, 2017; Kirkovski et al., 2013; Lai et al., 2011; Tierney et al., 2016; Trubanova et al., 2014; Young et al., 2018). In particular, relative to their ASD male peers, cognitively-able ASD females may demonstrate behavior within social contexts that superficially suggests better social skills, but that upon closer inspection conceal their autism-related challenges. These behaviors include appearing more socially motivated (Head et al., 2014), demonstrating more fluent use of verbal and non-verbal pragmatic markers (Parish-Morris et al., 2017) and showing greater facility in modulating behavior based on context (Hiller et al., 2014), along with showing a strong desire to be liked by others (Hiller et al., 2016), developing intense attachments to particular friends (Bargiela et al., 2016), and interacting with the same sex peer group in ways that give the superficial impression of ‘fitting in’ (Dean et al., 2014). This behavioral profile, along with potentially greater ‘masking’ of autism-related social difficulties (Allely, 2019; Lai et al., 2017; Schuck et al., 2019; Wood-Downie et al., 2020), is associated with increased negative outcomes in ASD females compared to their ASD male peers, among these, elevated risk for co-occurring mental health challenges, including depressive symptomatology (Oswald et al., 2016) and self-harm (Cassidy et al., 2018; Hirvikoski et al., 2016; Maddox et al., 2017).

To address these open questions in our understanding of the IQ-adaptive functioning gap, we examined a unique, sex-balanced sample of ASD youth (aged 8–17 years). In order to disentangle the possibility of typical sex effects in adaptive behavior from effects that may be specific to ASD females versus ASD males (Messinger et al., 2015), we compared ASD females and males to a group of their same-aged TD peers. Although TD individuals are expected to have adaptive skills commensurate with their intellectual functioning, (to our knowledge) no study has directly compared adaptive functioning of cognitively-able ASD youth to that of their TD peers. Direct comparison of ASD females and males with their same-sex peers is necessary to illuminate diagnosis- versus sex-specific differences in adaptive functioning profiles. It is important to note that analyses concerning sex differences are based on parent-reported sex assigned at birth, and data were not collected concerning gender identity, a point we return to in the Discussion.

We characterized adaptive functioning in three domains (Daily Living Skills, Communication and Socialization) utilizing the Vineland Adaptive Behavior Scales, Second Edition (Sparrow et al., 2005). We examined whether each of the four groups (ASD females (ASDf), ASD males (ASDm), TD females (TDf) and TD males (TDm)) evince a gap

between intellectual functioning (full-scale IQ) and adaptive skills in each of the three domains, using a proportion score in order to take into account differences in IQ between ASD and TD groups. We additionally explored associations between age and all of the following: IQ, adaptive functioning, and the IQ-adaptive functioning discrepancy. We used FSIQ (rather than verbal or non-verbal IQ), in part, to allow for comparison of the present study with previous literature that has also examined the gap between cognitive abilities, also indexed by FSIQ (and not IQ subscores), and adaptive functioning (Alvares et al., 2019; Bölte & Poustka, 2002; Duncan & Bishop, 2015; Kanne et al., 2011; Kraper et al., 2017; Pugliese et al., 2015) within cognitively-able samples.

We sought to replicate existing work characterizing ASD males by determining 1) whether the IQ-adaptive functioning discrepancy (reported in mostly or exclusively male ASD samples) also holds for ASDm in our sample; and 2) whether the association between adaptive functioning and age reported in the literature is found in our ASDm sample. We sought to extend the literature by answering the following questions: 1) does the IQ-adaptive functioning gap also characterize cognitively-able ASDf; and 2) is there an association between age and both adaptive functioning and the IQ-adaptive functioning discrepancy in ASDf. An exploratory aim of the study was to examine sex differences in the IQ-adaptive functioning gap. To this end, we compared ASDf and ASDm to their same-sex TD peers.

We predicted that both ASDm and ASDf in our sample would show a significant discrepancy between IQ and adaptive functioning, and that this discrepancy would be inversely associated with age (i.e., a widening IQ-adaptive functioning gap with increasing age). We predicted main effects for group (ASD vs. TD), with the TD group having higher adaptive functioning scores than the ASD group, and the ASD group having a greater IQ-adaptive functioning gap than the TD group.

## Methods

### Participants

Participants were youth aged 8–17 years recruited from the community for inclusion in ASD and TD groups as part of an NIH-funded Autism Centers of Excellence (ACE) network study (the ‘GENDAAR’ [Gender Exploration of Neurogenetics and Development to Advance Autism Research] project). The ACE network included four data collection sites (Yale University, University of Washington, Boston Children’s Hospital/Harvard Medical School, and University of California, Los Angeles), a data coordinating center at the University of Southern California, and a data analytic and study coordination center at the University of Virginia. Our sample included 355 youth (ASDf=75, ASDm=102, TDf=87, TDm=91).

Expert clinicians confirmed DSM-based ASD diagnoses using the diagnostic algorithm for either module 3 or module 4 of the Autism Diagnostic Observation Schedule, Second Edition (ADOS-2; Lord et al., 2012), *and* the Autism Diagnostic Interview-Revised (ADI-R; Rutter, Le Couteur, & Lord, 2008). Scores on the ADI-R were required to meet the measure’s algorithm cut-off for each of the three domains (10 for Social Interaction; 8 for Communication; and 3 for Restricted, Repetitive Behaviors & Interests) (Lord et al., 1994).

Study exclusionary criteria for both groups of participants included full-scale IQ (FSIQ) < 70; twin status; active seizures within the past year; or current use of any benzodiazepine, barbiturate, or anti-epileptic medication. Dosage of any other medication must have been stable for >6 weeks. Additional exclusionary criteria for the ASD group included significant pre- or perinatal injury (specifically, birth <36 weeks *and* birth weight <2000g; *or* hospital stay >3 days in neonatal intensive care); neonatal brain injury; neurological disorder involving pathology above the brainstem, aside from a history of non-focal, uncomplicated epilepsy; known genetic condition (e.g., Fragile X); medical conditions that are likely to be etiological (e.g., focal epilepsy); any known environmental factor that could account for the clinical presentation of ASD (e.g., severe malnutrition or psychological deprivation); clinically significant auditory or visual impairments after correction; or sensorimotor difficulties precluding valid use of diagnostic instrumentation.

Further exclusionary criteria for the TD group included diagnosed, referred, or suspected ASD; a first- or second-degree biological relative with diagnosed ASD; scores on measures of autism features suggestive of ASD or the broader autism phenotype (i.e., total *T*-score >60 on the Social Responsiveness Scale, Second Edition (Constantino & Gruber, 2012) or a raw score >11 on the Social Communication Questionnaire, Lifetime version (Lord & Rutter, 2003)); or clinical impression of ASD, the broader autism phenotype, or a developmental disorder. TD participants were also excluded if the parent reported referred or suspected psychiatric, learning, or other neurodevelopmental disorder; or if, based on clinician interpretation of measures that probe behavioral concerns related to DSM psychiatric disorders (Child and Adolescent Symptom Inventory (Gadow & Sprafkin, 2005), Child Behavior Checklist (Achenbach, 1991) a significant psychiatric disorder (i.e., psychiatric disorder that would prevent participation in daily activities (e.g., schizophrenia, bipolar disorder)) was suspected.

Parents provided written informed consent, and youth provided written assent. Procedures were conducted in compliance with ethical standards set forth by the universities' Institutional Review Boards and the Declaration of Helsinki.

**Community Involvement**—The PI of this ACE Network is a parent of autistic children. As such, he serves at the request of the Secretary of Health and Human Services as a public member on the Interagency Autism Coordinating Committee.

## Measures

**Adaptive Functioning**—Adaptive functioning was measured using the Vineland Adaptive Behavior Scales, 2nd edition [VABS-II] (Sparrow, Cicchetti, & Balla, 2005). Parents of ASD and TD participants were administered the semi-structured interview VABS-II, which is an age- (but not sex-) normed measure appropriate for individuals from birth to 90+ years. Three adaptive behavior domains were assessed: Communication (Receptive, Expressive, and Written subdomains), Daily Living Skills (Personal, Domestic, and Community subdomains), and Socialization (Interpersonal, Play and Leisure Time, and Coping Skills). Age-normed standard scores for VABS domains are calculated and range

from 20–160, with a mean of 100 and a standard deviation of 15; higher scores are indicative of better adaptive functioning.

**Full-Scale IQ**—Full-scale IQ (FSIQ) was estimated using participants' General Conceptual Ability Standard Score on the Differential Ability Scale, Second edition [DAS-II] (Elliott, 1990). The DAS-II provides a comprehensive assessment of cognitive functioning in youth ranging from 7.0–17.11 years. Age-normed standardized scores range from 30–170, with a mean of 100 and a standard deviation of 15.

**FSIQ-Adaptive Functioning Gap Proportion Scores**—Proportion scores of the difference between FSIQ and the VABS-II Daily Living Skills, Communication and Socialization domain scores were calculated as follows:  $\text{IQ-adaptive functioning gap proportion score} = (\text{IQ} - \text{Domain Score}) / \text{FSIQ}$  to index the IQ-adaptive functioning gap. Rather than a simple difference score, a proportion score was used in analyses testing for group and sex differences in order to take into account the higher FSIQ of the TD groups.

**Autistic Traits**—Parent-report on the Social Responsiveness Scale, Second Edition [SRS-2] (Constantino & Gruber, 2012) was utilized as a continuous measure of autistic traits. Raw scores from the aggregate domains of Social Communication and Interaction (SCI) and Restricted Interests and Repetitive Behavior (RRB) were used to characterize participants. Higher SRS scores reflect greater autistic traits.

## Data Analysis

Statistical analyses were conducted in R v.3.4.1. Prior to analyses, continuous variables were inspected to ensure assumptions of parametric statistical tests were met. If assumptions were not met within acceptable limits of skewness and kurtosis, non-parametric tests were used. Comparisons were conducted by group (ASD vs. TD) and by sex (m vs. f) on the following demographic variables: age, maternal highest level of education, race, and ethnicity. These comparisons were also conducted for FSIQ and VABS domain scores as well as SRS raw SCI and RRB aggregate scores. Within the ASD group, females and males were compared on ADI-R Reciprocal Social Behavior, Communication and Language, and Restricted, Repetitive Behaviors and Interests, and on ADOS-2 CSS scores.

**IQ versus Adaptive Functioning**—Paired-samples t-tests, separately for each of the four groups (ASDf, ASDm, TDf, TDm), were conducted to determine if FSIQ differed significantly from adaptive functioning in each of the VABS-II domains.

**IQ, Adaptive Functioning, and IQ-Adaptive Functioning Gap Proportion Scores: Correlations with Age**—Given that previous studies have shown that age-normed adaptive functioning scores do not keep pace with age-based expectations among cognitively-able ASD individuals, we examined associations between age and VABS-II composite domain scores, as well as between age and IQ, and between age and the IQ-adaptive functioning gap proportion scores.

**Group and Sex Differences in the IQ-Adaptive Functioning Gap Proportion Scores**—Group and sex differences in the discrepancy between IQ and adaptive

functioning were probed for the VABS-II domains (Communication, Daily Living Skills, and Socialization). To determine whether a model with an interaction of group  $\times$  sex  $\times$  age was appropriate, MANOVA models with and without these interactions were compared. As noted in the Introduction, participants were assigned female or male labels based on parent-reported biological sex at birth. No measure of gender identity was collected.

## Results

### Participant Characteristics

ASD and TD groups did not differ in their sex ratios ( $\chi^2(1, N=355)=1.5, p=.22$ ). For age and maternal level of education, neither significant group nor sex effects were found (see Table 1). Due to small cell sizes for race, categories were collapsed. There were no differences for proportion of participants who identified as Caucasian. Further, comparisons revealed similar proportions for participants who identified as being of Latinx descent. ASD youth showed significantly lower FSIQ compared to TD youth. Within the ASD group, ASDf and ASDm did not differ for IQ; however, within the TD group TDm had significantly higher FSIQ than TDf. Relative to their same-sex TD peers, ASD youth showed significantly lower adaptive functioning scores across all domains (see Table 1, Figure 1). Further, 26.7–44% of ASD youth fell below the cut-off of 70 on the VABS domain scores (see Table 1).

ASD youth showed significantly higher autistic trait ratings (SRS-2 SCI and RRBI) compared to TD youth. Within ASD and TD groups, females and males did not significantly differ for SCI or RRBI. ASDf and ASDm did not differ significantly on ADI-R Communication, Social or RRBI scores. Compared to ASDf, ASDm showed higher ADOS-CSS scores. See Table 1 for details.

### IQ versus Adaptive Functioning

A series of paired samples *t*-tests showed significantly greater FSIQ scores than each of the three VABS-II domain scores in all four groups (ASDf, ASDm, TDf, and TDm) examined separately (see Table 2, Figure 2).

### IQ, Adaptive Functioning, IQ-Adaptive Functioning Gap Proportion Score: Correlations with Age

There were no significant associations between FSIQ and age for any of the four groups (see Table 3). Among ASDf, age was significantly negatively correlated with Socialization, and Communication domain scores on the VABS-II, though not Daily Living Skills. For ASDm, as well as TDf and TDm, Socialization, Daily Living Skills, and Communication domain scores were all significantly negatively correlated with age.

For the IQ-adaptive functioning gap proportion score, among ASDm age was significantly positively correlated with the proportion score (i.e., the proportion score grew with increasing age) between IQ and adaptive functioning in Communication and Daily Living Skills, but not Socialization. Among ASDf, age was significantly positively associated with the proportion score for Communication and Socialization, but not Daily Living Skills. Although only ASDf showed a significant association between age and Socialization, and

only for ASDm was age significantly correlated with Daily Living Skills, correlation coefficients for the groups for these measures did not differ significantly (Daily Living:  $Z = -0.55$ ,  $p = .29$ ; Socialization:  $Z = 0.80$ ,  $p = .21$ ). Age was significantly positively correlated with the proportion score for the gap between IQ and adaptive abilities in all three VABS domains among TDf (Table 3). In TDm, positive correlations between age and the proportion score reach significance for only Daily Living Skills.

### Group and Sex Differences in IQ-Adaptive Functioning Gap Proportion Scores

The interaction of group  $\times$  sex  $\times$  age was examined. There was no significant interaction with age (i.e., there was no sex  $\times$  age, group  $\times$  age, or group  $\times$  sex  $\times$  age interaction). In analyses reported below, age was included as a covariate. In all analyses of group and sex differences in the IQ-adaptive functioning gap proportion scores, model comparisons revealed no interaction of group  $\times$  sex (see Figure 2); therefore, models without the interaction are reported.

In the overall MANCOVA model, using Pillai's trace, there was a significant main effect of group ( $V = .26$ ,  $F(348,3) = 40.6$ ,  $p < .0001$ ,  $\eta_p^2 = .26$ ), and sex ( $V = .052$ ,  $F(348,3) = 6.45$ ,  $p < .0001$ ,  $\eta_p^2 = .047$ ). In follow-up analyses, univariate ANCOVAs were used and Bonferroni correction with significant threshold was set at  $0.05/3 = .0167$ . Separate univariate ANCOVAs (for each of the VABS domains) showed a significant effect of group ( $F(350,1) = 53.7$ ,  $p < .0001$ ,  $\eta_p^2 = .14$ ) and a main effect of sex ( $F(350,1) = 14.06$ ,  $p = .0002$ ,  $\eta_p^2 = .034$ ) for the IQ-Communication gap proportion score, with ASD youth demonstrating a greater IQ-Communication skill discrepancy than TD youth, and males demonstrating a greater gap than their female counterparts. Similarly, for the IQ-Daily Living Skills gap proportion score, there were main effects of group ( $F(350,1) = 30.71$ ,  $p < .0001$ ,  $\eta_p^2 = .087$ ; greater in ASD than TD youth) and sex ( $F(350,1) = 12.12$ ,  $p = .0006$ ,  $\eta_p^2 = .029$ ; greater in m than f). For the proportion scores of the gap between Socialization and IQ, there was a main effect of group ( $F(350,1) = 101.3$ ,  $p < .0001$ ,  $\eta_p^2 = .23$ ; greater in ASD than TD youth), but the effect of sex was not significant ( $F(350,1) = 3.79$ ,  $p = .0522$ ,  $\eta_p^2 = .009$ ).

### Discussion

The current study examined group and sex differences in the discrepancy between IQ and adaptive skills among ASD and TD youth, utilizing, for the first time, a proportion score to account for 'baseline' group differences in FSIQ (i.e., higher FSIQ in TD youth). The results presented here for ASD and TD youth aged 8–17 years corroborate and extend the literature on the IQ-adaptive functioning gap in cognitively-able ASD individuals. We further show that a gap between IQ and adaptive functioning is attested in TD youth. We discuss these findings in turn, along with the implications the marked gap between IQ and Socialization may have for ASDf, in particular. Results presented for ASDm corroborate the existing literature that has examined predominantly male samples and has demonstrated a discrepancy between cognitive abilities and everyday adaptive functioning (Duncan & Bishop, 2015; Kraper et al., 2017). Extending the literature, we show ASDf evince a discrepancy in IQ and adaptive functioning consistent with the one reported in predominantly ASDm samples.



The current study confirms in a community-recruited cross-sectional sample that ASDm without ID, as a group, show a significant impairment in adaptive functioning across domains compared to their TD peers, and evince the prototypical autistic adaptive functioning profile (i.e., Communication > Daily Living Skills > Socialization). With respect to our main research questions, we corroborate the literature showing that ASDm in our sample: 1) show a discrepancy between cognitive functioning (FSIQ) and each domain of adaptive functioning; and 2) this discrepancy increases with age.

Extending the literature, we show that ASDf, like their same-aged male ASD peers demonstrate lower adaptive functioning compared to their same-sex TD peers (and also show the autistic profile of adaptive skills). In ASDf, as in ASDm, the IQ-adaptive functioning gap proportion score was positively associated with age for Communication; however, whereas ASDf showed a significant association between the proportion score and age for Socialization (but not Daily Living Skills), ASDm showed an association between age and the Daily Living Skills (but not Socialization) proportion score. Importantly, the magnitude of the effect in ASDf and ASDm groups is similar for age-Daily Living Skills correlations and for age-Socialization relationships, and correlation coefficients do not significantly differ. Interestingly, both ASDf and TDf (but neither ASDm nor TDm) show significant associations between the Socialization proportion score and age. In ASD youth, age is associated with adaptive functioning, but not IQ. Our findings are consistent with reports that ASD individuals do not demonstrate age-expected increases in adaptive functioning at the same rate as their TD peers during childhood and adolescence (Klin et al., 2007; Pugliese et al., 2015).

Further advancing our understanding of the IQ-adaptive functioning gap in cognitively-able ASD youth, our comparison of ASD and TD females and males reveals both diagnostic and sex differences in adaptive functioning and in the IQ-adaptive functioning gap. As predicted, ASD youth demonstrated lower adaptive functioning scores than TD youth, and adaptive functioning scores for both ASDf and ASDm were significantly lower than found in the same-sex TD groups. ASDf and ASDm did not significantly differ for adaptive skills in any of the VABS domains.

In examining the IQ-adaptive functioning gap, we further add to the literature, showing that not only ASD but also TD youth demonstrate a discrepancy between intellectual functioning and adaptive skills, and that as in the ASD group, this gap among TD youth increases with age.

These findings are not entirely surprising, given the differences in the psychometric properties of the measures of these two constructs and what we would expect in terms of adaptive functioning within this age group. While IQ captures the full range of intellectual functioning, assessments of adaptive functioning probe for skills needed to execute everyday activities and function independently. Importantly, although we observe an IQ-adaptive functioning gap in TD youth, it is quite small particularly when compared to the profound gap in these scores found in ASDf and ASDm.

Interestingly, a main effect of sex was found, indicating that males showed significantly lower adaptive functioning than females in Communication and Daily Living Skills, but not Socialization. These findings, if replicated, could suggest sex differences do exist in non-standardization TD samples, and this finding would aid the interpretation of sex differences that might be seen in ASD samples. It is important to note that adaptive functioning in TDM, though lower than TDF in these domains, is still solidly average and within the normal range. Thus, although we see similar sex-related patterns in ASD and TD youth, both ASDf and ASDm show marked challenges across adaptive functioning domains.

Although prior studies have not investigated potential sex differences in the IQ-adaptive functioning gap in ASD, they have examined sex differences in adaptive functioning alone. Several studies have shown overall decreased adaptive skills for ASDf relative to ASDm (Frazier et al., 2014; Ratto et al., 2018). Notably differing from our sample, Frazier et al.'s (2014) participants are from the Simons Simplex Collection, which has a low proportion of females with IQ  $\geq 80$ , and the females included had significantly lower IQ than the males. Additionally, Ratto et al. (2018) included participants who met *either* ADI-R or ADOS diagnostic criteria. When analyzing the effect of diagnostic measure (satisfaction of criteria on only one measure, or on both measures) and its interaction with sex, a main effect of sex and also a trend-level interaction between sex and measure(s) was found: there were greater sex differences among the subgroup that met criteria *only* on the ADOS, compared to those who met *both* ADOS and ADI-R criteria (the criterion for inclusion in the ASD sample analyzed here). Thus, results reported here may differ from patterns of results reported in the literature due to important sample-based differences.

For ASD youth, the discrepancy between IQ and adaptive functioning is particularly salient within the socialization domain. When considered alongside the unique presentation of ASD in cognitively-able females, the large IQ-adaptive functioning gap within the Socialization domain may have particularly negative consequences for ASDf. Distinct social challenges are faced by ASDf relative to ASDm (Tierney & Burns, 2017), as well as differing sex-based cultural and societal expectations (Halladay et al., 2015). ASDf are acutely aware of sex-based expectations and report struggling to conform to these expectations (Milner et al., 2019; Sedgewick et al., 2019). Camouflaging, or the masking of ASD-related social difficulties, occurs more often in females relative to their male peers (Dean et al., 2017; Hull et al., 2020; Kenyon, 2014; Lai et al., 2017; Schuck et al., 2019), and potentially reflects increased social motivation and insight into social challenges in ASDf compared to ASDm (Head et al., 2014). Negative outcomes among ASD women appear to be linked to social difficulties (South et al., 2019), and ASD women describe camouflaging as effortful and exhausting (Autistic Science Lady, 2018; Hull et al., 2017), and as having negative impacts on their well-being (Tierney et al., 2016; Tierney & Burns, 2017). Camouflaging appears to be associated with elevated risk for depression (Somerville et al., 2019) and suicidality (Cassidy et al., 2019). Thus, future studies should illuminate how the gap between intellectual ability and Socialization impacts ASDf in particular. More specifically, studies should examine the transitions into adolescence and young adulthood, which mark greater social demands that may outstrip camouflaging resources, along with increased difficulties in social functioning for ASDf (Kanfisz et al., 2017; Trubanova et al., 2014).

The current study has several limitations. Analyses reported here examine biological sex; therefore, we are unable to determine the influence of gender identity on adaptive functioning and the IQ-adaptive functioning gap. This is an important, open question to address in the future given increased gender variance in ASD (Strang et al., 2014, 2020) and the paucity of research into whether and how findings of sex differences may apply to gender diverse individuals.

Further, the sample investigated here is predominantly Caucasian and lacks desired racial and ethnic diversity (Mandell et al., 2009). This lack of diversity limits the ability to know how the findings reported here may generalize. The examination of group and sex differences in the discrepancy between cognitive ability and adaptive functioning within racially and ethnically representative samples is a critical area for future research.

Further, the sample analyzed is cross-sectional, and primarily composed of participants on the lower end of the age range studied (8–17y). This makes generalizability of the findings here to older adolescents less certain. Age may be a particularly important variable for ASDf, as discussed above, and a study sufficiently powered to detect the interaction of sex with age has reported greater problems in social adaptive functioning with increasing age in ASDf relative to ASDm (Mahendiran et al., 2019). Additionally, given the known male-skewed biases in ASD diagnostic measures (Lai et al., 2015; Loomes et al., 2017), our inclusion criteria using *both* the ADOS and ADI-R suggests that our ascertainment of participants may also be biased, potentially including those ASDf who more closely resemble the “male” presentation of ASD, while excluding ASDf who are the “best” camouflagers and who may therefore run the risk of being missed by standard diagnostic assessments. Studies examining the IQ-adaptive functioning gap and that implement less stringent criteria for inclusion in an ASD group (e.g., meeting on *either* the ADOS *or* ADI; *or* having a clinically diagnosed ASD) and that therefore may capture individuals with a potentially different profile of ASD features are warranted.

The findings reported here underscore the importance of providing appropriate services to cognitively-able ASD individuals. In particular, it appears that given the distinct findings in the literature for individuals with both ASD and ID as compared to non-ID ASD individuals, intellectual functioning may act as a gatekeeper, where a criterial level of intellectual functioning admits the achievement of a certain level of adaptive functioning, and increases in FSIQ *below* a certain threshold are associated with improvements in adaptive skills. However, *above* a certain threshold, and in particular within the “normal” range of IQ, increases in FSIQ are not associated with concomitantly augmented adaptive functioning. Future studies that include both ID and non-ID samples of individuals with ASD can examine this possibility empirically. It is critical, however, to note that in the ASD sample here, in which no FSIQ was less than 71, 27–40% of ASD individuals demonstrated adaptive functioning at or below cut-offs used in the diagnosis of ID and the determination of its severity. As such, evaluation of adaptive functioning and provision of appropriate support services among non-ID ASD individuals is necessary. Further, given that cognitively-able ASDf may present with a profile that obscures some of their social challenges, evaluating adaptive skills and providing services among this group may improve not only adaptive functioning, but also mental health outcomes.

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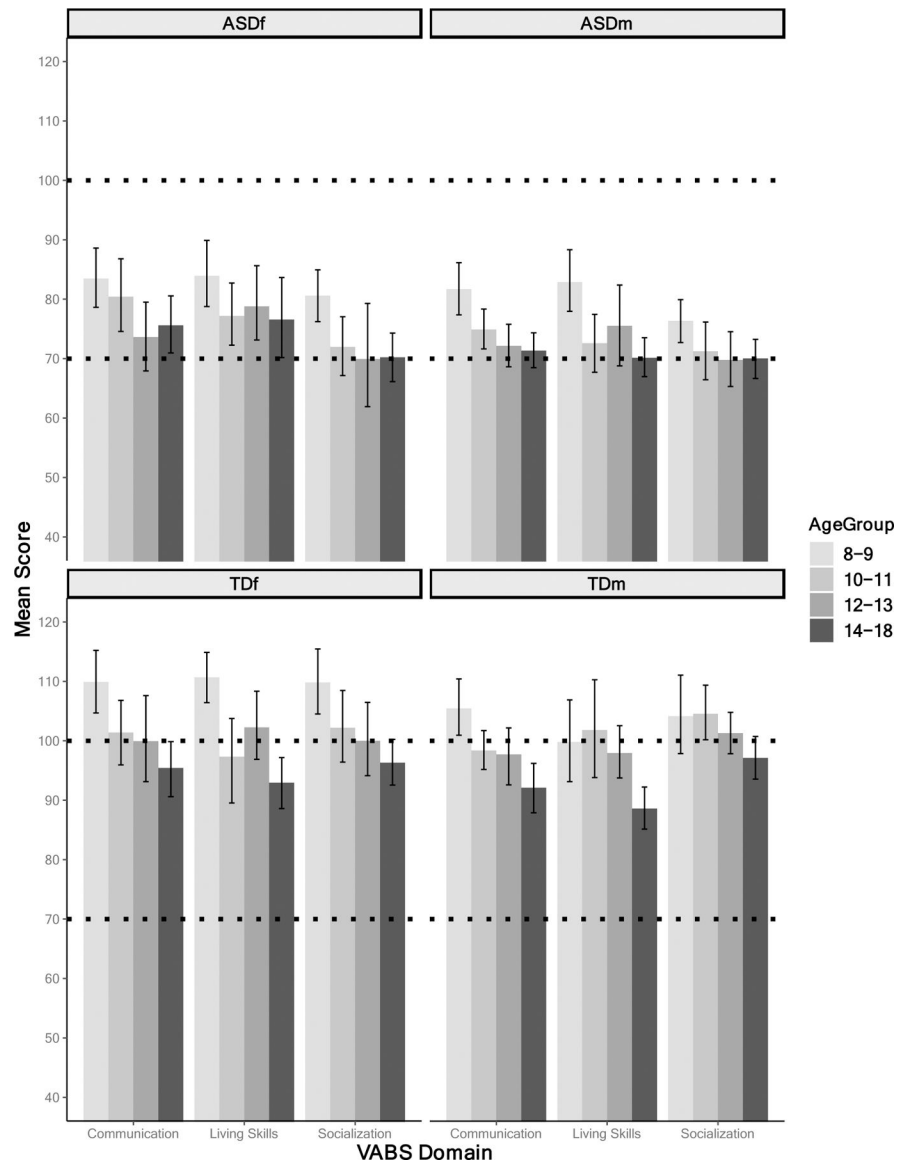
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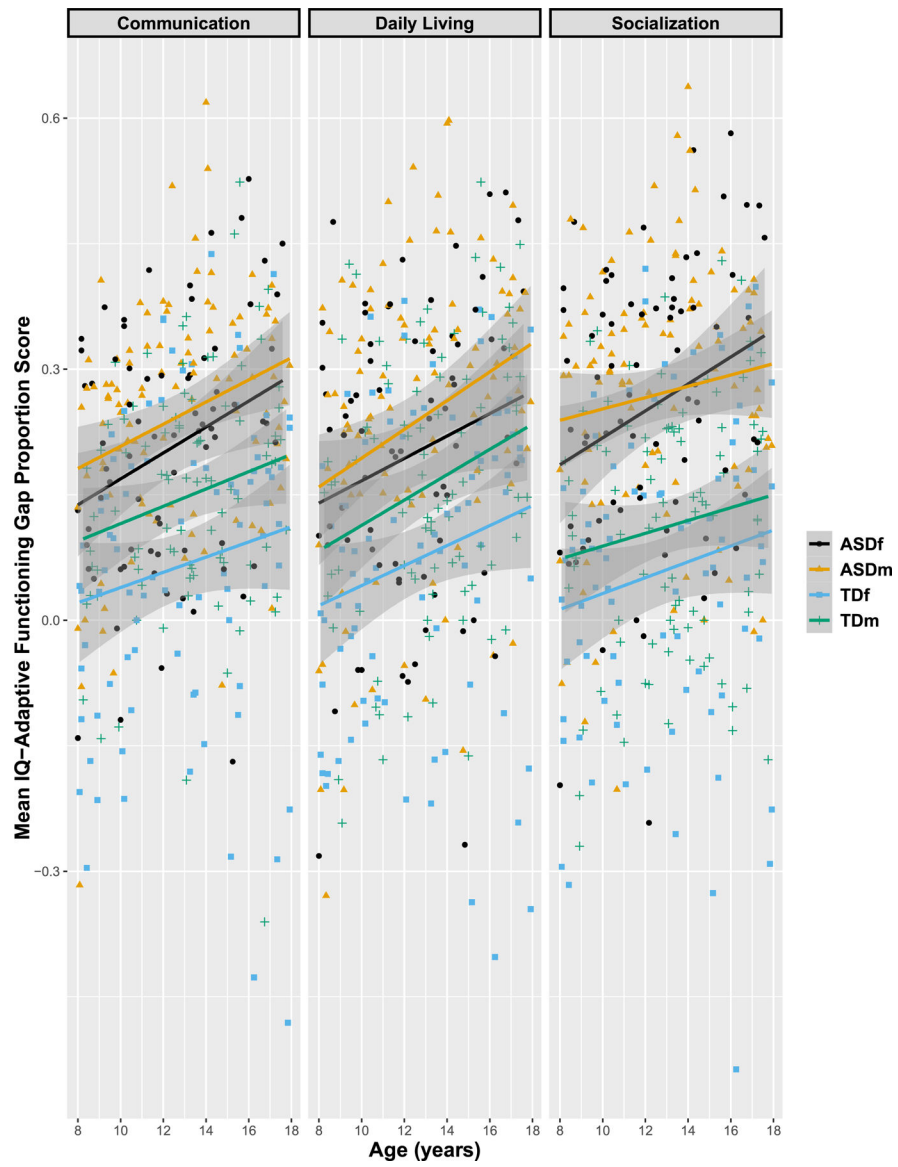
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**Figure 1.** Mean VABS-II domain composite scores, presented by age group. Notes: Ages are binned for visualization purposes only. Dotted lines at 100 and 70 represent standardized mean and clinical cut-off, respectively. Each error bar depicts 95% confidence interval.



**Figure 2.** Mean IQ-adaptive functioning gap proportion scores. Shading depicts 95% confidence intervals.

Table 1.

Participant characteristics.

	ASDf n=75	ASDm n=102	TDf n=87	TDm n=91	ASDf vs. TD	ASDm vs. TDm	ASDf vs. ASDm	f vs. m test statistics, p-values, effect sizes
<b>Age (years)</b>								
Mean(SD)	12.3 (2.76)	12.6 (3.0)	12.9 (3.18)	13.2 (2.72)	t(160)=-1.14, p=0.26, d=0.18	t(191)=-1.5, p=0.13, d=0.22	t(175)=-0.63, p=0.53, d=0.09	t(176)=-0.84, p=0.40, d=0.13
Range	8.0-17.6	8.0-17.9	8.1-17.9	8.3-17.8				
<b>Race, N(%)</b>								
African American	2 (2.66%)	6 (5.88%)	11 (12.64%)	2 (2.19%)	$\chi^2(1)=2.8$ , p=0.09, V=0.12	$\chi^2(1)=2.3$ , p=0.13, V=0.10	$\chi^2(1)=3.7$ , p=0.053, V=0.13	$\chi^2(1)=1.5$ , p=0.22, V=0.08
Asian	2 (2.66%)	1 (0.98%)	5 (5.75%)	7 (7.69%)				
Caucasian	60 (80%)	72 (70.58%)	62 (71.26%)	72 (79.12%)				
More than one	8 (10.66%)	22 (21.57%)	8 (9.19%)	9 (9.89%)				
Native American	0 (0%)	1 (0.98%)	0 (0%)	0 (0%)				
Undeclared	3 (4.0%)	0 (0%)	1 (1.15%)	1 (1.09%)				
<b>Ethnicity, N(%)</b>								
Latinx descent	10 (13.3%)	19 (18.6%)	22 (25.3%)	18 (19.8%)	$\chi^2(1)=3.6$ , p=0.06, V=0.14	$\chi^2(1)=0.06$ , p=0.81, V=0.004	$\chi^2(1)=0.68$ , p=0.41, V=0.05	$\chi^2(1)=0.94$ , p=0.33, V=0.06
Not of Latinx descent	62 (82.7%)	83 (81.4%)	62 (71.3%)	72 (79.1%)				
Undeclared	3 (4.0%)	0 (0%)	3 (3.4%)	1 (1.1%)				
<b>Maternal Education</b>	n=66	n=91	n=71	n=81				
Graduate degree	19	24	22	27	$\chi^2(6)=1.07$ , p=0.98, V=0.09	$\chi^2(6)=6.2$ , p=0.40, V=0.19	$\chi^2(6)=2.49$ , p=0.87, V=0.13	$\chi^2(6)=2.97$ , p=0.81, V=0.14
Partial graduate	5	5	6	5				
Bachelor's degree	20	23	20	28				
Associate's degree	3	7	5	3				
Partial college	12	22	13	12				
High school diploma	6	7	4	3				
Partial high school	1	3	1	3				
<b>FSIQ</b>								
Mean(SD)	100.7 (19.3)	101.1 (17.2)	109.9 (15.2)	115.3 (15.2)	t(160)=-3.4, p<0.0008**, d=0.53	t(191)=-6.0, p<0.0001†, d=0.87	t(175)=-0.14, p=0.89, d=0.02	t(176)=-2.3, p=0.02*, d=0.35
Range	71-162	71-160	79-147	79-149				

	ASDf n=75	ASDm n=102	TDF n=87	TDm n=91	ASD vs. TD test statistics, p-values, effect sizes	f vs. m test statistics, p-values, effect sizes
<b>VABS-II</b>						
<b>Communication</b>		n=101			κ(160)=-10.5,	κ(174)=1.9,
Mean(SD)	78.4 (12.7)	75 (10.7)	101 (14.3)	96.8 (12.7)	p<.0001 $\hat{\tau}$ , d=1.7	p=.056, d=-0.29
Median (Range)	77 (52-111)	74 (57-122)	101 (72-135)	97 (67-132)		p=.04 *, d=-0.30
<b>70. N(%)</b>	22 (29.3%)	37 (36.6%)	0 (0%)	2 (2.2%)	--	--
<b>Daily Living Skills</b>						
Mean(SD)	78.8 (14.0)	75.0 (13.1)	99.8 (14.2)	94.9 (13.6)	κ(160)=-9.4,	κ(175)=1.87,
Median(Range)	77 (54-112)	73.5 (51-119)	100 (58-130)	93 (69-129)	p<.0001 $\hat{\tau}$ , d=1.49	p=.06, d=-0.28
<b>70. N(%)</b>	20 (26.7%)	40 (39.2%)	2 (2.3)	1 (1.1%)	--	--
<b>Socialization</b>						
Mean(SD)	73 (12.7)	71.9 (10.9)	101 (13.5)	100 (11.1)	κ(160)=-13.7,	κ(175)=0.62,
Median(Range)	73 (46-118)	73 (43-107)	101 (68-145)	100 (76-127)	p<.0001 $\hat{\tau}$ , d=2.2	p=.54, d=-0.07
<b>70. N(%)</b>	33 (44%)	43 (42.2%)	1 (1.2%)	0 (0%)	--	--
<b>SRS-2 raw scores</b>						
SCI	n=69	n=89	n=81	n=89		
Mean(SD)	76.3 (20.0)	74.2 (22.3)	16.5 (11.4)	16.1 (13.7)	U=10.5,	U=10.9,
Median(Range)	75 (39-135)	71 (5-118)	13 (0-50)	12 (1-71)	p<.0001 $\hat{\tau}$ , r=.86	p<.0001 $\hat{\tau}$ , r=.82
RRB	n=69	n=90	n=81	n=85		
Mean(SD)	16.8 (6.4)	17.5 (6.6)	1.9 (2.8)	2.3 (2.8)	U=10.3	κ(157)=
Median(Range)	17 (4-33)	18 (0-32)	1 (0-20)	1 (0-16)	p<.0001 $\hat{\tau}$ , r=.84	U=-1.3, p=.19, r=-.10
<b>ADL-R, Mean(SD)</b>						
Social	18.5 (5.4)	19.4 (5.3)	--	--		κ(175)=-1.1, p=.29, d=0.16
Communication	15.6 (4.0)	16.2 (4.4)				κ(175)=-0.88, p=.38, d=0.13
RRBIs	5.6 (2.6)	6.3 (2.7)				κ(175)=-1.7, p=.10, d=0.26

	ASDf n=75	ASDm n=102	TDF n=87	TDm n=91	ASD vs. TD test statistics, p-values, effect sizes	f vs. m test statistics, p-values, effect sizes
					ASDf vs. TDF	ASDm vs. TDm
					ASDf vs. ASDm	TDF vs. TDm
<b>ADOS-2-CSS,</b>						
Mean(SD)	6.59 (1.85)	7.38 (1.87)	--	--	t(175)=-2.8, p=.005 <sup>**</sup> , d=0.43	

SD: standard deviation; FSIQ: full scale IQ; VABS-II: Vineland Adaptive Behavior Scales, 2nd edition; SRS-2: Social Responsiveness Scale, 2nd edition; SCI: Social Communication and Interaction; RRB: restricted and repetitive behaviors; ADI-R: Autism Diagnostic Interview-Revised; RRBIs: Restricted, Repetitive Behaviors & Interests; ADOS-2: Autism Diagnostic Observation Schedule, Second Edition; CSS: Calibrated Severity Score; 70, N(%): number and proportion of individuals who meet the VABS-II cut-off for 'low' adaptive functioning;  $\phi$ -Cohen's  $\phi$ ;  $V$ -Cramer's  $V$ ;  $r$ -effect size for non-parametric Mann-Whitney U-test. VABS-II domain scores are reported as standard scores (M=100, SD=15).

\*  $p < .05$   
 \*\*  $p < .01$   
<sup>†</sup>  $p < .0001$ .

**Table 2.**

IQ versus adaptive functioning within each group: paired-samples *t*-test statistics, *p*-values and effect sizes.

	ASD <i>n</i> =75		ASD <i>n</i> =102		TDF <i>n</i> =87		TD <i>n</i> =91	
	Test statistic	<i>p</i> -value, effect size	Test statistic	<i>p</i> -value, effect size	Test statistic	<i>p</i> -value, effect size	Test statistic	<i>p</i> -value, effect size
IQ vs. Communication	<i>t</i> (74)=-10.3, <i>p</i> <.00001 <sup>†</sup> , <i>d</i> =1.19		<i>t</i> (100)=-14.7, <i>p</i> <.00001 <sup>†</sup> , <i>d</i> =1.46		<i>t</i> (86)=-4.05, <i>p</i> <.0005 <sup>**</sup> , <i>d</i> =0.44		<i>t</i> (90)=-10.0, <i>p</i> <.00001 <sup>†</sup> , <i>d</i> =1.05	
IQ vs. Daily Living Skills	<i>t</i> (74)=-9.2, <i>p</i> <.00001 <sup>†</sup> , <i>d</i> =1.06		<i>t</i> (101)=-12.5, <i>p</i> <.00001 <sup>†</sup> , <i>d</i> =1.24		<i>t</i> (86)=-4.61, <i>p</i> <.00005 <sup>†</sup> , <i>d</i> =0.50		<i>t</i> (90)=-9.41, <i>p</i> <.00001 <sup>†</sup> , <i>d</i> =0.99	
IQ vs. Socialization	<i>t</i> (74)=-11.2, <i>p</i> <.00001 <sup>†</sup> , <i>d</i> =1.30		<i>t</i> (101)=-14.9, <i>p</i> <.00001 <sup>†</sup> , <i>d</i> =1.48		<i>t</i> (86)=-3.76, <i>p</i> <.0005 <sup>**</sup> , <i>d</i> =0.41		<i>t</i> (90)=-7.47, <i>p</i> <.00001 <sup>†</sup> , <i>d</i> =0.79	

SD: standard deviation

<sup>†</sup> *n*=101.

<sup>\*\*</sup> *p*<.01

<sup>†</sup> *p*<.0001.

**Table 3.**

IQ, Adaptive functioning, and IQ-adaptive functioning gap proportion scores: Correlations with age.

	ASDF <i>n</i> =75	ASDm <i>n</i> =102	TDF <i>n</i> =87	TDm <i>n</i> =91
	<i>r<sub>s</sub></i> , <i>p</i> -value	<i>r<sub>s</sub></i> , <i>p</i> -value	<i>r<sub>s</sub></i> , <i>p</i> -value	<i>r<sub>s</sub></i> , <i>p</i> -value
<b>FSIQ</b>	0.02, 0.90	-0.009, 0.92	-0.09, 0.40	-0.08, 0.46
<b>Adaptive Functioning</b>				
Communication	-0.26, 0.02 *	-0.41 <sup>†</sup> , 0.00002 <sup>†</sup>	-0.35, 0.001 **	-0.38, 0.0002 **
Daily Living Skills	-0.18, 0.11	-0.42, 0.00001 <sup>†</sup>	-0.45, 0.00001 <sup>†</sup>	-0.43, 0.00002 <sup>†</sup>
Socialization	-0.27, 0.02 *	-0.24, 0.02 *	-0.39, 0.0002 **	-0.28, 0.006 **
<b>IQ-Adaptive Functioning Gap</b>				
<b>Proportion Score</b>				
IQ-Communication	0.26, 0.027 *	0.29 <sup>†</sup> , 0.004 *	0.25, 0.022 *	0.20, 0.06
IQ-Daily Living Skills	0.20, 0.09	0.28, 0.004 *	0.28, 0.008 **	0.22, 0.04 *
IQ-Socialization	0.24, 0.035 *	0.12, 0.21	0.22, 0.039 *	0.11, 0.28

FSIQ: full-scale IQ; *r<sub>s</sub>*=Spearman's rho.

<sup>†</sup> *n*=101

\* *p*<.05

\*\* *p*<.01

<sup>†</sup> *p*<.0001.