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Exploring the effect of autistic traits on the relationship between adaptive behavior and
cognitive functioning in the Japanese representative population

(日本の一般集団における適応行動と認知機能の関連に対する自閉症特性の影響)

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Exploring the effect of autistic traits on the relationship between adaptive behavior and cognitive functioning in the Japanese representative population

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Conflict of interest

Authors declare no conflict of interest.

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SUMMARY

Background: The relationships between adaptive behavior (such as practical skills in daily life), cognitive functioning (such as intelligence quotient [IQ]), and autistic traits in the general population are not well researched. **Methods:** This study included 835 nine-year-old children from the Hamamatsu Birth Cohort Study for Mothers and Children (HBC Study). The associations between adaptive behavior and cognitive functioning were examined by IQ categories, levels of autistic traits, and their combinations using multiple regression analysis. **Results:** The association was positive for the total sample. The magnitude of the association weakened as IQ increased, but it was similar between children with lower and higher levels of autistic traits. When IQ and autistic traits were combined, the association was positive only in children with lower levels of autistic traits and within lower-than-average and average IQs. The predicted adaptive behavior score for cognitive functioning was approximately 10 points lower for those with higher levels of autistic traits than lower levels of autistic traits. **Conclusion:** Although the magnitude of the association was similar between children with lower and higher levels of autistic traits, those with higher levels of

autistic traits exhibited lower adaptive behavior, highlighting the need for tailored support in this group.

Key words: adaptive behavior, cognitive functioning, autistic traits, association, cross-sectional study

INTRODUCTION

Adaptive behaviors are social and practical skills,¹ and defined as the collection of skills that are learned and performed to meet society's expectations and demands, which are indexed on a person's chronological age and/or cultural group.^{2, 3} Therefore, a low level of adaptive behavior is considered a condition in which the individual is not living an age-appropriate daily life and is limited in social functioning.

Studies have indicated that adaptive behaviors are positively correlated with cognitive functioning in the general population.^{4, 5, 6} Cognitive functioning is usually measured with intelligent tests such as Wechsler's Intelligent Scales for Children,^{7, 8} and the most commonly used indicator is IQ, an indicator of one's cognitive assets. A recent meta-analysis (148 studies, n=16,468) reported a positive correlation ($r=0.51$) between adaptive behavior and cognitive functioning, indicating that cognitive functioning predicts adaptive behavior in a linear manner.⁹

However, the relationship between adaptive behavior and cognitive functioning in clinical populations differs from that observed in the general population. The aforementioned meta-analysis found that the correlations were moderated by the IQ ranges and disability types (e.g., neurodevelopmental disorders) of the study

participants.⁹ In particular, the magnitude of the correlation between adaptive behaviors and cognitive functioning was found to be much higher among individuals with an IQ below 70 ($r=0.60$), while it was relatively lower among individuals with IQ over 90 ($r=0.40$). Differences in the magnitude of correlations between individuals with autism ($r=0.54$) and without a clinical diagnosis ($r=0.39$) were also reported,⁹ suggesting that cognitive functioning may not represent the level of adaptive behavior in individuals without clinical diagnosis.

In the general population, autistic traits, which are defined as characteristics and behavioral tendencies associated with Autism Spectrum Disorder (ASD),¹⁰ are continuously distributed, and ASD is the extreme end of this continuum, and cognitive functioning is also distributed on a continuum. The relationship between adaptive behavior and cognitive functioning in individuals diagnosed with ASD or intellectual disability has been well studied. However, few studies have addressed these traits or functioning in a continuous manner, which are continuously distributed in the general population. Although adaptive behavior has been shown to be influenced by intellectual functioning and autistic symptoms, their combination has been rarely studied. Furthermore, studies have pointed out that children with ASD have compromised skills

in adaptive behavior compared to children without ASD,¹¹ but less attention has been paid to children with autistic traits who are below the threshold for clinical diagnosis. In this study, we will focus on autistic traits, including subthreshold of clinical diagnosis.

This study aimed to investigate the association between adaptive behavior and cognitive functioning stratified by 1) IQ categories (lower-than-average, average, and higher-than-average), 2) levels of autistic traits (higher and lower), and 3) the combination of IQ categories and autistic traits levels in a representative sample of school-aged children. Considering the related literature, we hypothesize that the magnitude of the associations between adaptive behavior and cognitive functioning would differ according to IQ ranges (low, normal, and high) and the levels of autistic traits. Specifically, the magnitude of the association, represented by regression coefficients, is predicted to be stronger in children with lower-than-average IQ and weaker in those with higher IQ. In addition, higher levels of autistic traits are predicted to enhance the magnitude of the association. Given that both IQ and autistic traits contribute to the strength of this relationship, a combined effect of these factors may further amplify the association.

METHODS

This study had a cross-sectional design and was conducted as part of the Hamamatsu Birth Cohort Study for Mothers and Children (HBC Study). HBC Study was designed to elucidate the early developmental trajectories of children living in Japan.^{12, 13} One of the main purposes of HBC Study was to detect developmental patterns of children who are later diagnosed with neurodevelopmental disorders. Among such conditions, ASD has been focused on considerable attention because early detection and diagnosis of ASD is one of the major focuses of public health strategy.

Participants

The HBC Study included 1,258 children born to mothers recruited at Hamamatsu University Hospital and Kato Maternity Clinic in Japan between December 24, 2007, and June 30, 2011. Recruitment was carried out for all pregnant women in the first or second trimester of pregnancy. Participants were consecutively enrolled in the HBC Study. Following the initial assessments conducted up to the age of 2, follow-up evaluations were scheduled at age 4, 6, 9. The present study included children aged 9

who were assessed for adaptive behaviors, cognitive functioning, and autistic traits at follow-up assessments in the original cohort. Children diagnosed with Down syndrome were excluded from the analysis because they were reported to demonstrate a specific relationship between adaptive behavior and cognitive function.¹⁴ Based on the above inclusion and exclusion criteria, 835 children (66.4%) were included in this analysis.

Ethical considerations

This study was approved by the Ethics Committee of the Hamamatsu University School of Medicine (17-037, 17-037-3, 20-233). Written informed consent was obtained from all caregivers for their own participation and their children's participation.

Measurement

Adaptive Behavior

Adaptive behavior was measured using the Japanese version of Vineland Adaptive Behavior Scales second edition (VABS-II),^{4, 5} which is a standardized measure of daily living functioning for individuals aged 0 to 90 years, based on interviews with parents

and guardians. The VABS-II consists of four domains: communication, daily living skills, social skills, and motor skills (up to 6 years of age). Measurements of motor skills are not feasible for children above age 6, therefore motor skills were not measured in this study. The scores of the adaptive behavior composite and each domain were converted to Japanese standard scores with a mean (M) of 100 and standard deviation (SD) of 15.

Cognitive functioning

The Japanese version of Wechsler Intelligence Scale for Children, Fourth Edition (WISC-IV) was used to assess cognitive functioning.^{7, 8} Full-scale IQ (FSIQ) standardized in the Japanese population (M=100, SD=15) was used in this study. To stratify the associations between adaptive behavior and cognitive functioning by IQ, we classified IQ into three categories based on the mean and SD: lower-than-average (IQ<85), within-average (IQ 85–114), and higher-than-average (IQ≥115).

Autistic traits

We used the Japanese version of the Social Responsiveness Scale Second Edition (SRS-2). It is a 65-item parent-reported quantitative measure of communication reactions associated with autistic traits, including social awareness, social cognition, social communication, social motivation, restricted interests, and repetitive behaviors.^{15,16} This study used a gender-standardized total T-score standardized in the Japanese population. According to the SRS-2 manual, a total T-score of 59 or less is considered within the typical range.^{15,16} In this study, participants with a cut-off score of 60 (i.e., +1 standard deviation; SD) or higher were described as children with a higher level of autistic traits and those with a score of 59 or less were categorized as having a lower level of autistic traits.

Covariates

Based on previous studies, variables that may affect cognitive function or adaptive behavior, or both, were included as covariates: the gender of the children,¹⁷ parental age at birth,^{18, 19} parental education level,²⁰ household income,²¹ and birth order.²²

Statistical analysis

In the multiple regression models, we first analyzed the association between the composite score of adaptive behavior and cognitive functioning, while adjusting for covariates. The analyses were further stratified according to the IQ categories and autistic traits. We used categorized variables to examine the potential nonlinearity of the association between adaptive behavior and cognitive functioning and the threshold effect of autistic traits. However, the classification of autistic traits using a cutoff value of 60 may oversimplify the continuum. The classification also has the weakness of reducing the amount of information that a continuous quantity can provide. Therefore, we conducted a sensitivity analysis in which cognitive functioning and autistic traits were treated as continuous variables. In this analysis, an interaction between cognitive functioning and autistic traits was included to examine whether the magnitude of the association between adaptive behavior and cognitive functioning differed depending on the presence or absence of autistic traits. Each model in the multiple regression analysis was adjusted for the available covariates. Statistical analysis was performed using the STATA software version 14.0,²³ and p -value < 0.05 was defined to be statistically significant.

RESULTS

Table 1 shows the characteristics of the total sample and the two groups of children: those with higher and lower levels of autistic traits. A total of 835 children aged nine years were included, of which approximately half were male (51.3%) and first-born children (50.2%). Approximately 16% of the children had high levels of autistic traits. Since +1 SD or more was categorized as a higher level of autistic traits in this study, it is reasonable that 16% of the total distribution falls into this category. Some of these children are considered to have autistic traits below the diagnostic threshold and do not necessarily have a clinical diagnosis. Differences in demographic characteristics were found in adaptive behavior (VABS-II composite score), cognitive functioning (FSIQ), and autistic traits (SRS-2 total T-score) between two autistic trait groups. Differences were also found in birth order and paternal age when the participating children were born.

The overall correlation between adaptive behavior and cognitive functioning was positive and moderate ($r=0.30$). Table 2 shows the association between adaptive behavior and cognitive functioning stratified by IQ categories and levels of autistic traits. As for the stratification by IQ categories, two of the regression coefficients for the

association were positive (coefficient [B]=0.69, 95% confidence interval [CI]:0.38 to 1.01, $P<0.001$ for lower-than-average [IQ<85]; B=0.17, 95% CI:0.05 to 0.29, $P=0.004$ for average [IQ 85–114]), although the association was not significant in the higher-than-average group [IQ $\geq$ 115] (B=-0.05, 95% CI: -0.28 to 0.19, $P=0.69$). As for stratification by levels of autistic traits, both regression coefficients were positive (B=0.17, 95% CI:0.11 to 0.24, $P<0.001$ for lower level [SRS-2 <60]; B=0.28, 95% CI:0.13 to 0.44, $P<0.001$ for higher level [SRS-2 $\geq$ 60]).

Table 3 presents the regression coefficients for the association between adaptive behavior and cognitive functioning stratified both by IQ categories and levels of autistic traits. Positive associations were found only in two out of six stratified blocks: the lower-than-average IQ [IQ<85] group (B=0.62, 95% CI: .019, 1.05, $P=0.006$) and the average IQ [IQ 85–114] group (B=0.12, 95% CI: .0005, 0.25, $P=0.049$) in children with lower level of autistic traits. No significant association was found in those with higher-than-average [IQ $\geq$ 115] stratum and higher levels of autistic traits. Figure 1 further depicts the relationship between adaptive behavior and cognitive functioning, stratified by IQ categories and levels of autistic traits. The results of the sensitivity analysis

showed that the interaction effect of cognitive functioning and autistic traits on adaptive behavior was not significant ($B=0.02$; 95%CI: -0.01, 0.06).

DISCUSSION

This study investigated the association between adaptive behavior and cognitive functioning stratified either by IQ categories or autistic traits, and the combination of the two strata. Adaptive behaviors were positively associated with cognitive functioning in nine-year-old children as a whole and, as hypothesized, the association differed according to IQ ranges. The strongest associations were observed in children with lower-than-average IQ ($IQ < 85$), whereas no significant association was found in children with higher-than-average IQ ($IQ \geq 115$). However, contrary to the hypothesis that higher levels of autistic traits are predicted to enhance the magnitude of the association, the magnitudes of the associations were comparable between the higher and lower levels of autistic traits groups. Especially when stratified by IQ categories and levels of autistic traits, no significant associations were found in any IQ category in children with higher levels of autistic traits. In contrast, significant associations were

observed only in children with lower levels of autistic traits within the lower-than-average and average IQ categories. It is notable that, across all IQ categories, children with higher levels of autistic traits consistently exhibited lower adaptive behavior scores across all IQ categories compared to those with lower levels of autistic traits.

In this study, the association between adaptive behavior and cognitive functioning was positive in the total sample, which is consistent with the findings of the meta-analysis (correlation coefficient of 0.51).⁹ However, the magnitude of association became smaller and converged toward the null value as IQ increased, and there was no significance in the higher-than-average group. This is consistent with the suggestion that the correlations between adaptive behavior and cognitive functioning are weaker in higher-IQ categories,⁹ whereas in lower-IQ categories, these are closely related and inseparable.²⁴

Moreover, the aforementioned study indicated that the adaptive behavior-cognitive functioning correlation was stronger in children with intellectual disorder or autism than in those without any such disorders.⁹ We found that the association was significant for both the higher and lower levels of autistic traits, and the difference in the coefficients was minimal. This study provides the insight that the magnitude of the association

between adaptive behavior and cognitive functioning are similar, regardless of the presence or absence of autistic traits in the representative population.

In this study, as shown in Table 3, when both IQ and autistic traits were categorized, children with lower-and average-IQ and a lower level of autistic traits showed significant associations, whereas children with a higher level of autistic traits did not. This finding contradicts a previous report that found a greater association in individuals with autism than those without a clinical diagnosis.⁹ There are three possible explanations for this inconsistency. First, the focus of the present study was on autistic traits, which encompass a wider range of autism levels than clinically diagnosed autism. Even if autistic traits are continuous in the general population, there may be crucial differences between individuals with clinical diagnosis of ASD and those without diagnosis, for example, in terms of social adaptation. Additionally, VABS-II scores are centered on typically developing individuals; therefore, they may not accurately reflect the social adaptation of children with higher autistic traits or those diagnosed with autism. The emphasis on basic functional competencies may fail to detect subtle, context-dependent social difficulties—particularly in individuals with milder traits, higher cognitive functioning, or those who employ compensatory strategies to navigate

social environments. Furthermore, behaviors associated with autistic traits may be misinterpreted as personality characteristics (e.g., shyness or individual preference), resulting in an underestimation of actual difficulties. These findings may have led to the inconsistent results in previous reports. Second, the small sample size of the group with higher levels of autistic traits may have compromised the precision of the statistical analyses of the subgroups. Further subdivisions based on the IQ reduced the sample size. Therefore, the difference in the results from previous reports could be attributed to the lack of statistical power in this study. Third, the direction and the magnitude of the association may vary by subdomain of adaptive behavior.²⁵ From mid-school age onward, adaptive behavior was measured using three components: communication, daily living skills, and socialization. Communication and daily living skills are closely related to cognitive functioning, whereas socialization is not.²⁶ However, similar to the findings of the present study, Hill et al. reported that for children with higher intellectual functioning, greater ASD symptom severity was associated with better adaptive functioning than that of those with lower ASD symptom severity.²⁷ Future studies should examine differences in associations by subdomain of adaptive behavior with larger sample sizes.

Children with ASD generally have a lower social function than those with typically developing children,²⁸ thus, a reduction in adaptive behavior scores can occur depending on the presence and severity of autistic traits. This is consistent with the findings of prior studies, indicating that adaptive behavior is lower in individuals with ASD.²⁹ In this study, the predicted adaptive behavior for cognitive functioning was 9 to 12 points lower for higher levels of autistic traits (Fig. 1). When predicting the adaptive behavior of children with higher levels of autistic traits, there can be a reduction of approximately 10 points compared with children with lower levels of autistic traits or typically developing children with similar IQs. However, adaptive behavior can change over the course of life.³⁰ Support should be directed toward modifiable adaptive behavior, facilitating its continuous modification in response to dynamic environmental conditions. Given that adaptive behavior evolves over time in response to both developmental maturation and environmental demands, future longitudinal research is warranted to examine whether the associations observed in childhood persist, intensify, or diverge during adolescence and adulthood. Such investigations could provide valuable insights into the long-term implications of subthreshold autistic traits and their impact on functional outcomes across different life stages.

Limitations

The strength of this study was the relatively large sample size to investigate the association between adaptive behavior and cognitive function considering autistic traits. However, this study had several limitations that should be considered. First, autistic traits were classified using the cut-off scores of the SRS-2. The classification was based on statistical indices using quantitatively measured scores. To address this limitation, we conducted a sensitivity analysis in which the IQ and SRS-2 scores were treated as continuous variables. We found no interaction effects between IQ categories and autistic traits, confirming that the association between adaptive behavior and cognitive function was not moderated by autistic traits. In addition, it was unknown how many children with autistic traits above the statistical cut-off scores would be clinically diagnosed. Future studies using larger samples and considering both autistic traits and diagnostic information are needed. Second, both VABS-II and SRS-2 are parent-completed assessments. Parents who rated their children's levels of autistic traits as high were more likely to rate their children's adaptive behaviors as low. This means that these scores may be similar, and higher scores on the SRS-2 (i.e., higher ratings of autistic

traits) may be related to lower ratings of adaptive behavior. This may cause the potential for overestimation or underestimation of the association. Future studies should confirm whether the results of this study can be replicated including information on the clinical diagnosis of ASD based on objective assessments. Third limitation is due to the characteristics of the scales. Since VABS was developed as a measure to be used as a measurement for intellectual disability, its strength is ruling-in/ruling out what is defined as “significant deficits.”³ This characteristic of the scale may have influenced the results of this study, especially the average or above-average levels of adaptive behavior. Finally, the diagnoses of neurodevelopmental disorders, including ASD, remain unknown. Adaptive behaviors are affected by attention deficit/hyperactivity disorders, learning disabilities, emotional and behavioral disorders, and neurological disorders.³ Therefore, these diagnoses need to be considered in future studies.

CONCLUSION

In conclusion, adaptive behaviors and cognitive functioning are associated in a representative sample of Japanese children aged 9. The hypotheses of the present study

are based on evidence suggesting that the association between adaptive behavior and cognitive functioning tends to be stronger among individuals with lower cognitive functioning and neurodevelopmental conditions. In the present study, the magnitude of the association weakened as IQ increased, and this trend was similar for children with both higher and lower autistic traits. Since the present study examined a wider range of autistic traits in the representative population, the level of autistic traits may be milder than that of diagnosed ASD. Nevertheless, individuals with higher levels of autistic traits exhibited adaptive behavior scores approximately 10 points lower than those with lower levels of autistic traits. A continuum-based approach enables examination of how even subclinical levels of autistic traits may influence developmental outcomes, and highlights the need to consider individual variability across the full range of functioning. The results of this study suggest that, regardless of cognitive functioning, children with higher levels of autistic traits required support for adaptive behaviors that continue to develop after adolescence. Such support would include inclusive support that respects individual diversity, ensuring access to education at each person's own pace, and providing tailored support that meets each individual's unique needs. In addition to fostering inclusive educational environments that respect individual

diversity, it is essential to provide individualized support tailored to each developmental stage. Early screening for autistic traits, including those below diagnostic thresholds, is critical for facilitating timely intervention and preventing the accumulation of disadvantage. Furthermore, the allocation of resources in education and welfare should be guided not solely by formal diagnoses, but by the diverse developmental needs that span the life course. A life-course approach to comprehensive support holds significant potential to enhance long-term quality of life and to mitigate broader societal burdens.

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Table 1. Sample Characteristics

	total	lower level of autistic traits	higher level of autistic traits	difference testing
	(n=835)	(n=700)	(n=135)	
Age, mean (SD)	9.0 (2.2)	9.0 (2.2)	9.0 (2.0)	t (833) =0.20, p=0.84
Sex (male), n (%)	428 (51.3)	352 (50.3)	76 (56.3)	χ^2 (1) =1.64, p=0.20
Birth order (Primipara), n (%)	419 (50.2)	336 (48.0)	83 (61.5)	χ^2 (1) =8.23, p=0.004
VABS-II Composite, mean (SD)	101.2 (11.9)	103.0 (11.2)	91.7 (10.8)	t (833) =10.85, p<0.01
WISC-IV Full-Scale IQ, mean (SD)	101.7 (13.9)	102.5 (13.4)	97.3 (15.8)	t (833) =3.98, p<0.01
SRS-2 Total T-score, mean (SD)	51.0 (9.9)	47.7 (6.1)	68.1 (7.7)	t (833) =-33.86, p<0.01

Mother's age at birth, mean (SD)	32.0 (5.0)	32.0 (5.0)	32.4 (5.4)	t (833) =-1.09, p=0.28
Father's age at birth, mean (SD)	33.7 (5.8)	33.5 (5.7)	34.8 (6.2)	t (833) =-2.44, p=0.01
Mother's education (years), mean (SD)	14.0 (1.9)	14.0 (1.9)	13.7 (1.7)	t (833) =1.76, p=0.08
Father's education (years), mean (SD)	14.2 (2.7)	14.3 (2.6)	13.9 (2.9)	t (833) =1.47, p=0.14
Annual household income (million yen), mean (SD)	6.17 (284.5)	6.19 (285.7)	6.06 (279.0)	t (833) =0.51, p=0.61

Table 2. Overall association between adaptive behavior and cognitive functioning and the associations stratified by IQ categories and autistic traits

	Sample size	B (95% CI), P-value
Total	n=835	0.23 (0.17, 0.30), P<0.001
Lower-than-average IQ (FSIQ<85)	n=72	0.69 (0.38, 1.01), P<0.001
Average IQ (FSIQ 85–114)	n=617	0.17 (0.05, 0.29), P=0.004
Higher-than-average IQ (FSIQ≥115)	n=146	-0.05 (-0.28, 0.19), P= 0.69
Lower level of autistic traits (SRS-2 total T-score <60)	n=700	0.17 (0.11, 0.24), P<0.001
Higher level of autistic traits (SRS-2 total T-score≥60)	n=135	0.28 (0.13, 0.44), P<0.001

Abbreviations: B, regression coefficients; 95% CI, 95% confidence interval

Table 3. Associations between adaptive behavior and cognitive functioning stratified by both IQ categories and autistic traits; regression coefficients, the 95% confidence intervals, and P-values

	Lower-than-average IQ (FSIQ<85)	Average IQ (FSIQ 85–114)	Higher-than-average IQ (FSIQ≥115)
Lower level of autistic traits (SRS-2 total T-score <60)	0.62 (0.19, 1.05), P=0.006	0.12 (0.0005, 0.25), P=0.049	-0.06 (-0.30, 0.17), P=0.59
Higher level of autistic traits (SRS-2 total T-score≥60)	0.38 (-0.13, 0.89), P=0.13	-0.07 (-0.41, 0.28), P=0.71	0.48 (-1.13, 2.08), P=0.53

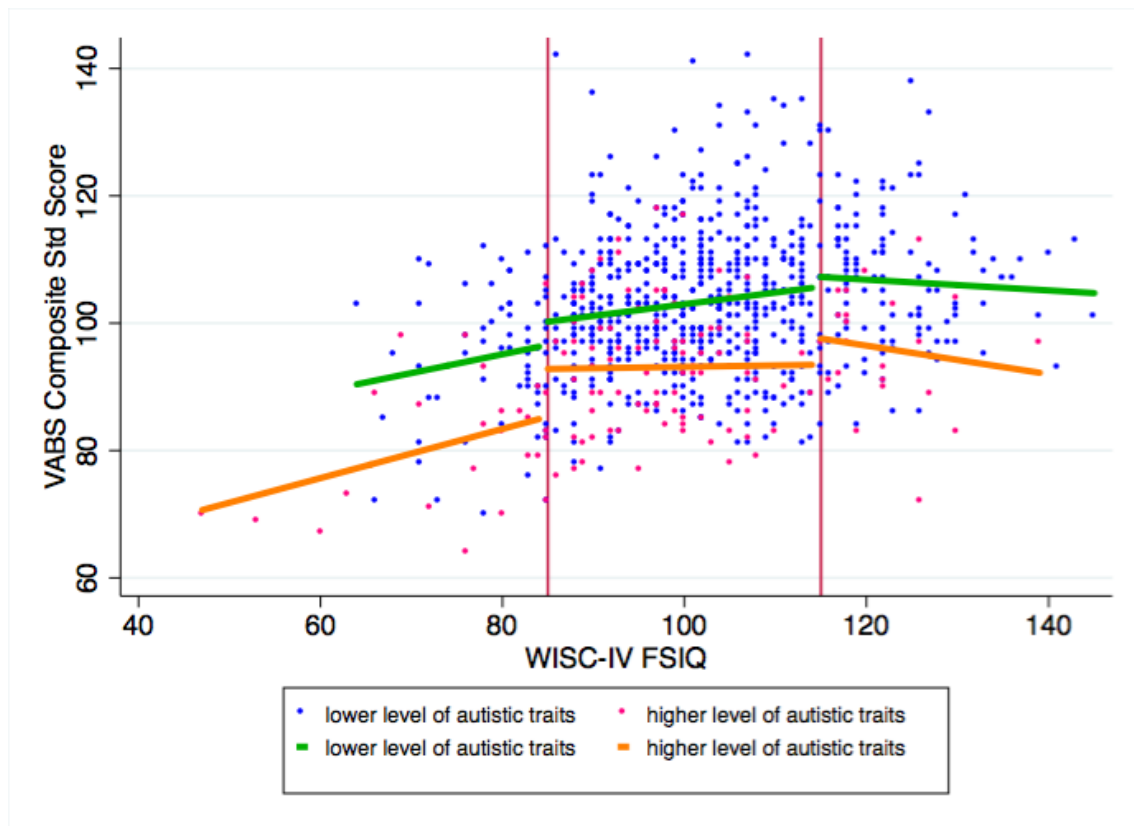


Figure 1. Fit plot stratified by both IQ categories and autistic traits.

The blue dots represent adaptive behavior and cognitive functioning in children with lower levels of autistic traits, and the green lines represent the predictive lines of the association. Similarly, the pink and orange lines represent associations in children with higher levels of autistic traits.