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Growth mixture models of adaptive behavior in adolescents with autism spectrum disorder

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Abstract

This study examined growth trajectories of teacher-reported adaptive behavior in a diverse sample of adolescents with autism spectrum disorder. The participants were 244 adolescents between the ages of 14 and 21 years who were assessed at up to four time points across two and a half years of high school. Demographic variables (age, sex, race, maternal education), phenotypic characteristics (intelligence quotient, autism severity) and school factors (location of the school, school quality) were collected. Growth mixture modeling was used to identify distinct classes of growth trajectories in communication, daily living skills, and socialization domains of adaptive behavior. Two distinct classes were identified for each domain. The first class had moderately low adaptive behavior scores and demonstrated growth of adaptive behavior over time and the second class had low adaptive behavior scores and did not demonstrate change over time. Adolescents within the moderately low adaptive behavior classes were younger at enrollment in the study, had higher IQs, and lower autism symptom severity. Logistic regressions were performed, and aspects of school quality predicted the likelihood of being in the moderately low classes above and beyond autism symptoms.

Keywords

adaptive behavior, adolescents, autism spectrum disorders, development

Introduction

Autism spectrum disorder (ASD) is characterized by difficulties in social communication skills and restrictive and repetitive behaviors (American Psychiatric Association, 2013). The prevalence of ASD has increased from 1 in 150 children in 2000 to approximately 1 in 59 children with a diagnosis of ASD in 2014, now indicating that there is currently an increased population of adolescents with ASD (Baio et al., 2018; Christensen et al., 2016; Rice, 2007). Despite the increasing prevalence and growing body of research for individuals with ASD, adults with ASD experience poor outcomes, such as unemployment and low participation in the community (Chan et al., 2017; Shattuck et al., 2012; Taylor et al., 2015; Taylor and Mailick, 2014; Woodman et al., 2015). Symptoms of ASD are typically lifelong, although there is heterogeneity across time among individuals with ASD (Billstedt et al., 2007; Georgiades et al., 2013; Munson et al., 2008; Szatzmari et al., 2015). Despite heterogeneity in ASD symptoms and variability in intelligence quotient (IQ), parents and caregivers of individuals with ASD typically report difficulties in adaptive behavior (Kanne et al., 2011; McDonald et al., 2015).

Adaptive behavior involves everyday skills such as communication (e.g. understanding, expressing, and writing language), daily living skills (e.g. hygiene, safety skills, cooking), and socialization (e.g. forming friendships, participating in leisure activities, coping strategies) (American Association on Intellectual and Developmental Disabilities (AAIDD), 2013; Sparrow et al., 2005). For individuals with developmental disabilities, including ASD, adaptive behavior is associated with employment, independent living, and quality of life during adulthood

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(Bishop-Fitzpatrick et al., 2016; Farley et al., 2009; Taylor and Mailick, 2014; Woolf et al., 2010). Adaptive behavior deficits in young adults with ASD without intellectual disability are associated with psychiatric comorbidities (Kraper et al., 2017). There is a critical need to understand the development of adaptive behavior in adolescence to identify potential targets for intervention programs and schools to promote positive outcomes in adolescence and young adulthood.

Adolescence may be a critical period to promote positive adult outcomes. However, there are few comprehensive studies with diverse and large samples that examine developmental outcomes, such as adaptive behavior. The use of large samples allows for the characterization of heterogeneity of longitudinal change between and within individuals. Growth mixture modeling (GMM) is a statistical approach that identifies subgroups within a sample rather than characterizing average change of the entire sample (Grimm et al., 2017). Identifying subgroups of individuals with ASD allows the potential to develop targeted interventions for subgroups of individuals with differential patterns of development. To our knowledge, only one study (Baghdadli et al., 2012) has used this approach to examine adaptive behavior of adolescents with ASD, and no studies have examined adolescents within the school context using teacher reports of adaptive behavior. The high school setting may be an optimal setting for targeted interventions (Odom et al., 2018). Therefore, characterization of adaptive behavior from teacher reports will inform our understanding of the development of adaptive behavior in the school setting to inform school-based interventions. This study examined developmental trajectories in adaptive behavior as reported by teachers in high school students with ASD and the impact of program quality on these trajectories.

Adaptive behavior and ASD

Extant research on adaptive behavior in youth with ASD suggest adaptive behavior deficits compared to both typically developing peers and children with other developmental disabilities (Duncan and Bishop, 2015; MacDonald et al., 2013; O'Donnell et al., 2012; Paul et al., 2014). From toddlerhood to young adulthood, adaptive behavior skills improve as a function of age (Bal et al., 2015; Freeman et al., 1999; Smith et al., 2012). The Pathways in ASD study is an ongoing study examining developmental trajectories of children with ASD in Canada. Flanagan et al. (2015) examined adaptive behavior from diagnosis of ASD to school entry at age 6 and reported that the majority of adaptive behavior standard scores remained relatively stable over time. In a larger sample of the Pathways longitudinal study, Szatmari et al. (2015) identified three distinct trajectory groups, with a majority of individuals showing moderate and stable adaptive behavior standard scores and the other two groups being high and improving or low and worsening from ages 3 to 6. Farmer et al. (2018) identified two distinct trajectories in children between the ages of 3 to 8 years of age, with a majority of individuals having low and worsening adaptive behavior standard scores and the second group being moderate and stable. This sample had less participants with moderately low intellectual functioning than the Szatmari et al.'s (2015) sample which may indicate why their study did not identify individuals who were high and improving (Farmer et al., 2018).

In two studies characterizing daily living skills from childhood to adulthood, daily living skills were reported to increase from childhood to adolescence (Bal et al., 2015; Smith et al., 2012). Freeman et al. (1999) reported gains in communication, daily living skills, and socialization skills from toddlerhood to young adulthood. With a group of 152 children and youth with autism aged 5–15 years, Baghdadli et al. (2012) identified differential trajectories of adaptive behavior age-equivalent scores in subgroups of participants across the communication, daily living skills, and socialization domains. Two communication developmental trajectories emerged, a group characterized by low growth and linear growth and a second group characterized by quadratic growth with more growth in childhood than adolescence. One daily living skills trajectory emerged with a quadratic growth suggesting more growth in childhood than adolescence. Two quadratic socialization trajectories emerged with a low growth group with acceleration in childhood and stability in adolescence, and a stronger growth group with more growth in childhood than adolescence (Baghdadli et al., 2012). Taken together, findings from these studies provide support for the growth of adaptive behavior over time, but skills are delayed compared to their typically developing peers. There is evidence for distinct subgroups of children with ASD with different patterns of development of adaptive behavior. These studies exclusively used parent reports, standard, and age equivalency scores, and have not examined adaptive behavior exclusively during adolescence.

Individual characteristics

Several characteristics of individuals with ASD have been identified of significant predictors of adaptive behavior across the lifespan. IQ and cognitive functioning significantly predict adaptive behavior in childhood, adolescence, and adulthood (Baghdadli et al., 2012; Bal et al., 2015; Freeman et al., 1999; Smith et al., 2012; Szatzmari et al., 2015). Although individuals with higher IQs are more likely to have higher adaptive behavior than individuals with intellectual disability, there is still a large gap between their IQ scores and their adaptive behavior scores (Duncan and Bishop, 2015; Kanne et al., 2011; Kraper et al., 2017; Matthews et al., 2015; Perry et al., 2009). Autism severity,

fewer hours of early intervention services, younger ages, comorbid health conditions, lower levels of maternal education, and poorer executive function skills have been associated with poorer adaptive behavior outcomes across the lifespan (Baghdadli et al., 2012; Chang et al., 2013; Duncan and Bishop, 2015; Kanne et al., 2011; Pugliese et al., 2015, 2016; Smith et al., 2012).

School factors

The school environment for individuals with ASD may be an important predictor of adaptive behavior. Inclusion in the general education classrooms has been associated with increased adaptive behavior for individuals with intellectual and developmental disabilities (Hunt and McDonnell, 2007). Inclusion during the school years has also been associated with positive outcomes in adulthood, including daily living skills, controlling for autism symptoms and intellectual disability (Woodman et al., 2016). However, these studies only measured time in classroom, not the quality of the inclusive environment. Furthermore, these studies assessed adaptive behavior using parent report rather than teacher report. To further investigate the impact of the school environment, examination of aspects of school quality may provide insights into how school environments influence adaptive behavior in adolescents with ASD. A recently developed measure of school quality, the Autism Program Environmental Rating Scale (APERS), provides a comprehensive examination of programs to include multiple aspects of the school environment, such as the organization and social climate of the classroom, instructional practices of teachers, and involvement of the student, family, and multiple staff members of the school (Odom et al., 2018).

Present study

The first goal of this study was to identify groups of individuals with ASD who have similar developmental trajectories during high school on the adaptive behavior domains of communication, daily living skills, and socialization as reported by teachers. The second goal was to test for group differences in demographic variables (age, biological sex, ethnicity, maternal education), phenotypic characteristics (IQ, autism severity), and school factors (location of school, school quality). Based on previous research, we expected that individuals with ASD with higher IQs and less severe autism symptoms would be more likely to belong to a class with better adaptive behavior skills and positive growth trajectories than individuals with lower IQs and more severe autism symptoms (Baghdadli et al., 2012; Bal et al., 2015; Szatzmari et al., 2015). Finally, the third goal was to examine the extent to which aspects of school quality predicted group membership. We hypothesized that higher levels of school quality would be associated with more optimal trajectories of adaptive behavior.

Method

Participants

Participants were drawn from a larger randomized controlled trial of a comprehensive treatment model for high school students with ASD, the Center on Secondary Education for Students with Autism Spectrum Disorder (CSESA; $N=546$). Participants in this study were drawn from the control group who were receiving services as usual (i.e. 30 high schools). Adolescents, their parents, and teachers were recruited at each high school site. High schools were recruited across central North Carolina, central and northern Wisconsin, and southern California. Selection criteria were that schools (a) were part of a local education agency and not charter or private schools, (b) included inclusive (i.e. students with ASD spending 80% or more time in general education classes) and/or self-contained programs for students with ASD, and (c) enrolled students with and without disabilities. Randomization occurred at the district level. Adolescents and parents consented to their participation and the study was conducted in compliance with the University of North Carolina at Chapel Hill Institutional Review Board (IRB; #13-3002).

Adolescents were enrolled in the study if they (a) had an educational classification of autism, (b) were between 13 and 22 years old, (c) were to be in high school for 2 years after enrolling in the study, and (d) did not have significant visual or hearing impairments. The individuals included in this study were 244 high school students with ASD and their parents and teachers. Participants were between the ages of 13 and 20 years ($M=16.4$, SD = 1.50) at the time of enrollment in the study. Demographics and descriptive information about the adolescents are included in Table 1.

Procedure

Trained research staff administered an assessment battery at up to four time points from 2014 to 2017 in a 2- to 3-year period. Time 1 was conducted in the fall of the school's first year of participation in the study ($N=244$), Time 2 was conducted at the end the first school year ($N=241$), and Time 3 ($N=221$) was conducted at the end of the second year. Time 4 included a smaller subset in the spring of the third school year ($N=88$). The battery included direct assessments and questionnaires completed by the students, parents, and teachers. Parents elected to complete the questionnaires via mail or through an online survey. Teachers included case managers, classroom teachers, or autism support teachers with knowledge of the adolescent with ASD. Teachers could complete questionnaires on multiple students if applicable.

Table 1. Participant characteristics at enrollment in the study.

Variable	*N*	%	*M*	SD
Age	244		16.4	1.5
Biological sex				
Male	207	84.8		
Female	37	15.2		
Ethnicity				
American Indian/Alaskan Native	6	2.7		
Asian	14	6.3		
Black or African American	33	14.8		
White	142	63.7		
Multi/biracial	15	6.7		
Other	13	5.8		
Location				
Urban	216	88.5		
Rural	28	11.5		
Maternal education				
Sixth–eighth grade	2	1.1		
Partial high school	4	2.1		
High school degree/GED	29	15.3		
Associate/technical degree or some college	59	31.2		
Bachelor's degree	57	30.2		
Masters/doctoral degree	38	20.1		
Nonverbal IQ	225		84.6	27.7
<70	63	28.0	48.7	11.9
70–100	88	39.1	85.4	10.6
>100	74	32.9	114.2	10.0
Autism symptoms				
Social Communication Questionnaire	190		21.4	7.1
Social Responsiveness Scale	220		70.4	11.8

SD: standard deviation; GED: General Education Diploma; IQ: intelligent quotient.

Measures

Individual characteristics. The age (in years), biological sex, and ethnicity of the adolescent were recorded at Time 1. For this study, ethnicity was coded as 1 = white/nonhispanic and 0 = nonwhite.

Family characteristics. Maternal education was recorded at Time 1. For this study, maternal education was coded as 0 (*high school degree or less*) and 1 (*more than high school degree*).

Nonverbal IQ. Nonverbal IQ was assessed using the *Leiter International Performance Scale, 3rd edition* (Leiter-3; Roid et al., 2013). The Leiter-3 is a standardized nonverbal assessment of intelligence and cognitive abilities for individuals aged 3–75 years. This study used the Brief IQ comprising the cognitive scales: Sequential Order, Form Completion, Classification and Analogies, and Figure Ground. The Brief IQ yields a nonverbal IQ score ($M = 100$, SD = 15).

Autism symptoms. Parents completed the *Social Communication Questionnaire* (SCQ; Rutter et al., 2003) as a measure of lifetime communication skills and social functioning in individuals with ASD. Parents rate whether behaviors have occurred during any point in their child's life as 0 (*No*) or 1 (*Yes*). A score of 15 or greater is considered an indication of possible diagnosis of ASD.

Teachers completed the *Social Responsiveness Scale, 2nd edition* (SRS-2; Constantino and Gruber, 2012). The SRS-2 is a standardized assessment of presence and severity of social skill deficits for individuals with ASD ages 2.5–18 years of age. The SRS-2 assesses social skills in 65 items across four domains: social awareness, social cognition, social communication, social motivation, and restrictive interests and repetitive behavior. Teachers rate behaviors from 0 (*Not True*) to 4 (*Almost Always True*) with higher scores indicating greater presence and severity of social skill deficits. Although not used for diagnoses of ASD, a *T*-score is calculated that is associated with severe deficiencies related to a clinical diagnosis of ASD. A score of 76 or higher is indicative of severe deficiencies, 66–75 = moderate deficiencies, 60–65 = mild deficiencies, and 59 and below = within typical limits. The SRS-2 *T*-scores were used in the current analyses.

School quality. The *Autism Program Environment Rating Scale* (*APERS*; Odom et al., 2018) was used to assess the quality of high school program environment. The *APERS* includes 60 items across 10 domains: environment, climate, assessment, instruction, communication, social, independence, functional behavior, family, and teaming. See Table 2 for domain definitions. Trained coders assess the items through observing classes and contexts for students with ASD for 3–4 hours across 2 days. Coders also interview lead teachers, team members, and family members, as well as review the student's Individual Education Plan and any other relevant documentation. Items are rated on a five-point scale, with one indicating the poorest quality and five indicating the highest quality (Odom et al., 2018).

The *APERS* was assessed in standard diploma and modified diploma programs for each high school in the CSESA at the beginning of the school year at Time 1 of the study. A total of 60 standard programs and 47 modified diploma programs were evaluated. A second trained reliability coder independently scored the APERS for approximately 20% of the sample. The mean inter-rater agreement within one rating point was 95.2% and exact agreement was 76.5%. The intraclass correlation coefficient (ICC) was 0.56 (Odom et al., 2018).

Adaptive behavior. Teachers completed the *Vineland Adaptive Behavior Scales—2nd edition Teacher Rating*

Table 2. Autism Program Environment Rating Scale domains.

Domain	Description
Learning	Classroom and school environment
Climate	Staff behaviors and interactions with students
Assessment	Development and data collection on Individualized Education Program goals and transition planning
Instruction	Instructional format, clarity, opportunities, and implementation
Communication	Use of assessments to inform modes of communication and instruction on communication goals and use of communication systems
Social	Arranging opportunities for social interactions, modeling social skills and relationships, explicit social skill instruction, and inclusion of peers
Independence	Support and strategies to support student's self-advocacy, independence in routines and activities, self-management, and planning
Functional behavior	Address interfering behaviors
Family	Team members development of relationships and frequent communication with family members
Teaming	Team members experience and involvement in providing services to students

Form (*Vineland-II TRF*; Sparrow et al., 2005). The Vineland-II TRF is a standardized assessment of adaptive behavior for students 3–22 years old across three domains: communication, daily living skills, and socialization. Each domain is composed of three subdomains. The communication domain includes the receptive, expressive, and written subdomains. The daily living skills domain includes the personal, academic, and school community subdomains. The socialization domain includes the interpersonal relationships, play and leisure time, and coping skills subdomains. The teaching version differs from the parent version primarily in the daily living skills domain by including the academic and school community subdomains rather than the domestic and community subdomains taking into account adaptive behavior skills in the school setting. Descriptions of the domains and item examples are provided in Table 3 (Sparrow et al., 2005). The Vineland-II TRF has demonstrated high internal consistency (rs = 0.84–0.96) and test–retest reliability (rs = 0.83–0.97). The Vineland-II TRF also demonstrates evidence for the internal structure of the theoretical construct of adaptive behavior providing evidence for the domains of Adaptive Behavior, Communication, Daily Living Skills, and Communication. In addition, the Vineland-II TRF has been used in clinical groups with older students with intellectual disability and students with ASD (Sparrow et al., 2005). The current sample had similar intercorrelations among subdomains in the Vineland-II TRF (rs = 0.35–0.87) as reported from the standardization sample (rs = 0.65–0.77) (Supplement 1).

Teachers rate the degree to which the adolescents demonstrate skills from 0 (*Never*) to 2 (*Usually*). Standard scores are provided for each domain and an adaptive behavior composite ($M = 100$, SD = 15). Higher scores indicate better adaptive behavior skills. Scores are categorized as Low (<70), Moderately Low (71–85), Adequate (86–114), Moderately High (115–129), and High (130–160) (Sparrow et al., 2005). For the GMMs, the Vineland Adaptive Behavior Scale (VABS)-II raw scores were used in order to characterize the growth of skills over time.

Analytic plan

The first objective of this study was to characterize the heterogeneity of adaptive behavior during high school in individuals with ASD by identifying discrete groups of adolescents with ASD in communication, daily living skills, and socialization domains of adaptive behavior. GMM was performed to identify and characterize classes of high school students with ASD over a two-and-a-half-year period. A two-level GMM was conducted using Mplus version 8 using a cluster variable of school to take into account the nesting of students within schools (Muthén and Muthén, 1998–2017). GMM identifies unobserved classes of individuals within a dataset that have similar trajectory differences in how classes change over time. For each individual in the dataset, GMM provides a posterior estimate of the probability of class membership indicating the likelihood that an individual belongs to a specific class (Grimm et al., 2017; Ram and Grimm, 2009).

Change in communication, daily living skills, and socialization domains from the VABS-II Teacher Report were modeled as a function of time for up to four time points across two and a half years during high school. Raw scores were used to capture change in skills over time (Grimm et al., 2017). Full information maximum likelihood (FIML) estimation was used to handle the incomplete adaptive behavior data. FIML is recommended for dealing with missing longitudinal data and uses all available data when fitting the GMM (Allison, 2012; Grimm et al., 2017). GMMs were fitted for each domain for one-, two-, and three-class models. Bayesian information criteria (BIC), Akaike information criteria (AIC), and sample size–adjusted Bayesian information criteria (ABIC) were used to compare the fit of the models. Models with lower

Table 3. Vineland Adaptive Behavior Scales—Teacher Rating Form item examples (Sparrow et al., 2005).

Domain	Description	Item examples
Communication		
Receptive	What student understands	Listening to instructions, informational talks
Expressive	How student uses spoken language	Staying on topic in conversations, describing goals
Written	What student reads and writes	Reading level, writing papers
Daily living skills		
Personal	How student dresses, eats and prepares food, and uses personal hygiene	Maintains neat appearance, buttons small buttons
Academic	What student understands about time, money, and math	Demonstrates understanding of fractions, multiplications, and computer skills
School community	How student follows rules, uses routines, and focuses in the classroom	Checks own work, stays on tasks, uses independent work time productively
Socialization		
Interpersonal relationships	How student interacts with peers	Starts small talk, initiation of conversations
Play and leisure	How student uses leisure time	Shows good sportsmanship, plays simple games
Coping skills	How student demonstrates sensitivity to others and responsibility	Accepts suggestions and mild teasing from others

AIC, BIC, and ABIC are favored (Grimm et al., 2017; Ram and Grimm, 2009). In addition, entropies were examined to determine classification quality. Models with values approaching 1 indicate that classes are more easily distinguished (Grimm et al., 2015). Entropies > 0.80 are considered good evidence that there is distinct separation of classes based on the posterior probabilities (Clark and Muthen, 2009).

The second objective was to examine group differences in demographic variables, phenotypic characteristics, and school factors in high school students with ASD. Class membership was recorded for each individual based on the best fitting GMM. Independent-samples *t*-tests were performed to characterize differences between individuals in the communication, daily living skills, and socialization groups in demographic variables (age, biological sex, ethnicity, maternal education), phenotypic characteristics (IQ, autism severity), and school factors (location of school, school quality) at Time 1, or time of enrollment in the study.

Finally, for our third aim, a domain of school quality and parent-reported lifetime autism symptoms were included in a logistic regression model to identify the extent to which school quality at Time 1 predicted class membership controlling for autism symptoms. We employed multiple imputation for missing data using SPSS version 24 on all of the demographic variables, phenotypic characteristics, and school factors. Multiple imputation uses the observed data to simulate values for the missing data across multiple datasets. The multiple datasets are analyzed separately and results are combined to produce overall unbiased estimates (White et al., 2011). The greatest missingness was found for the parent report of autism symptoms (22.1%) and maternal education (22.5%). Participants did not differ on individual characteristics from individuals with missing data from Time 1 to Time 3. Participants who had complete data at Time 4 were younger than participants with missing data and mothers had higher education. Given the nature of the school-based sample, some participants had aged out of the school during the fourth time point, so this difference was expected. Age and maternal education were used as covariates in the logistic regression. The results present the estimates pooled across 23 datasets based on the recommendation to impute at least one data set per percentage of missing data (Li et al., 2015; White et al., 2011).

Results

GMMs

GMMs were performed using raw scores separately for each domain of adaptive behavior. The fit statistics displayed in Table 4 indicated that the two-class models were the most appropriate for the communication and socialization domains of adaptive behavior. For the daily living skills domain, the three-class model had the lowest BIC and AIC indicating the most appropriate fit. However, examination of the posterior probabilities and model parameters of the daily living skills classes for the two- and three-class models suggested that the two-class model more accurately distinguished daily living skills trajectories between groups of individuals. The third class in the three-class model consisted of 2% of the sample, or four individuals, suggesting that this latent class may not be meaningful (Grimm et al., 2017; Jung and Wickrama, 2008). Consequently, two-class models consisting of Class 1 (moderately low adaptive behavior + growth) and Class 2 (low adaptive behavior + no growth) were selected for each domain of adaptive behavior.

Table 5 contains the growth parameters for adaptive behavior domains by class. The moderately low adaptive behavior + growth class in communication, daily living

Table 4. Fit statistics for adaptive behavior growth mixture models.

	Communication			Daily living skills			Socialization		
	Linear	Two-class	Three-class	Linear	Two-class	Three-class	Linear	Two-class	Three-class
Class proportions	1.0	0.87/0.13	0.68/0.19/0.13	1.0	0.89/0.11	0.87/0.11/0.02	1.0	0.82/0.18	0.61/0.21/0.18
AIC	5552	5418	5424	5181	5063	5034	5927	5864	5874
BIC	5590	5466	5483	5219	5111	5093	5965	5912	5933
ABIC	5555	5422	5429	5184	5067	5039	5930	5868	5879
Entropy		0.968	0.574		0.976	0.955		0.892	0.499

AIC: Akaike information criteria; BIC: Bayesian information criteria; ABIC: sample size–adjusted Bayesian information criteria.

Table 5. Growth parameters for adaptive behavior domains by class.

Adaptive behavior domain	Moderately low adaptive behavior + growth class	Low adaptive behavior + no growth class
	Est. (SE)	Est. (SE)
Communication		
Intercept	111.9 (1.35)***	39.9 (4.32)***
Linear slope	1.85 (.660)**	−1.12 (1.70)
Daily living skills		
Intercept	97.8 (.914)***	43.6 (4.10)***
Linear slope	1.32 (.586)*	−.508 (2.45)
Socialization		
Intercept	89.2 (1.76)***	36.4 (3.70)***
Linear slope	3.94 (1.03)***	−1.28 (1.90)

SE: standard error; *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

Table 6. Adaptive behavior raw scores by class over time.

	Moderately high and growth	Low and no growth
Communication		
T1	111.7 (16.5)	41.5 (3.56)
T2	113.0 (15.0)	37.3 (18.8)
T3	115.0 (15.6)	37.2 (20.0)
T4	115.0 (17.6)	38.3 (19.9)
Daily living skills		
T1	97.9 (12.6)	44.1 (14.1)
T2	98.2 (11.8)	42.0 (13.4)
T3	100.2 (11.8)	40.6 (16.2)
T4	99.8 (12.8)	46.3 (10.1)
Socialization		
T1	89.1 (18.8)	31.5 (14.4)
T2	92.1 (18.3)	35.8 (18.4)
T3	96.3 (17.5)	34.3 (19.3)
T4	94.7 (18.7)	32.8 (11.0)

skills, and socialization accounted for the majority of the sample. Individuals in the moderately low adaptive behavior + growth class had significantly higher adaptive behavior scores than the low adaptive behavior + no growth class (see Table 6). In addition, the moderately low adaptive behavior + growth class displayed improvements in adaptive behavior over time, whereas the low adaptive behavior + no growth class did not see a significant change in adaptive behavior over time. Individuals in the moderately low adaptive behavior + growth class gained 1.85, 1.32, and 3.94 in communication, daily living skills, and socialization skills a year, respectively. The trajectory for each class was plotted for communication (Figure 1), daily living skills (Figure 2), and socialization (Figure 3).

Demographic and descriptive characteristics of classes

Independent *t*-tests were performed to examine differences in classes in biological sex, age at enrollment, ethnicity, school location, nonverbal IQ, autism symptoms, and school quality. Table 7 displays imputed demographic and descriptive variables that further characterize individuals who were determined to be members of the two classes. Classes significantly differed on communication, daily living skills, and socialization standard scores across all four time points (Supplement 2).

Members of the moderately low adaptive behavior + growth class had significantly lower ages at enrollment in study, higher IQs, and less severe autism symptoms as rated by parents on the SCQ and teachers on the SRS across communication, socialization, and daily living skills at Time 1. Classes also differed significantly on the SRS across all four time points (Supplement 2). The classes did not differ on biological sex, location, or maternal education. Classes did not differ on total school quality. However, classes in the communication and daily living skills domains differed on the Independence domain of school quality. The moderately low adaptive behavior + growth class had a significantly higher program quality score in independence than the low + no growth class. 2. In the socialization domain, classes had no significant differences in school quality across domains.

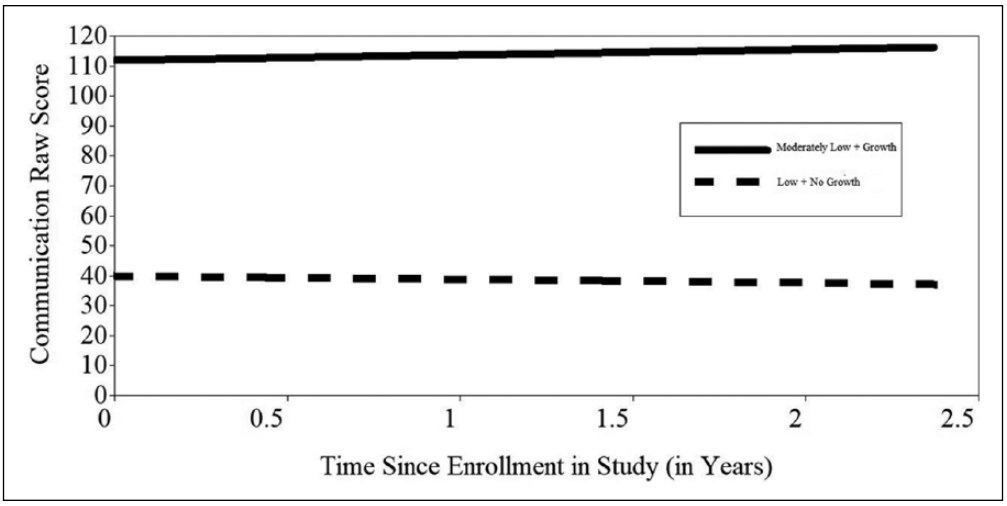

Figure 1. Growth mixture models of communication raw scores.

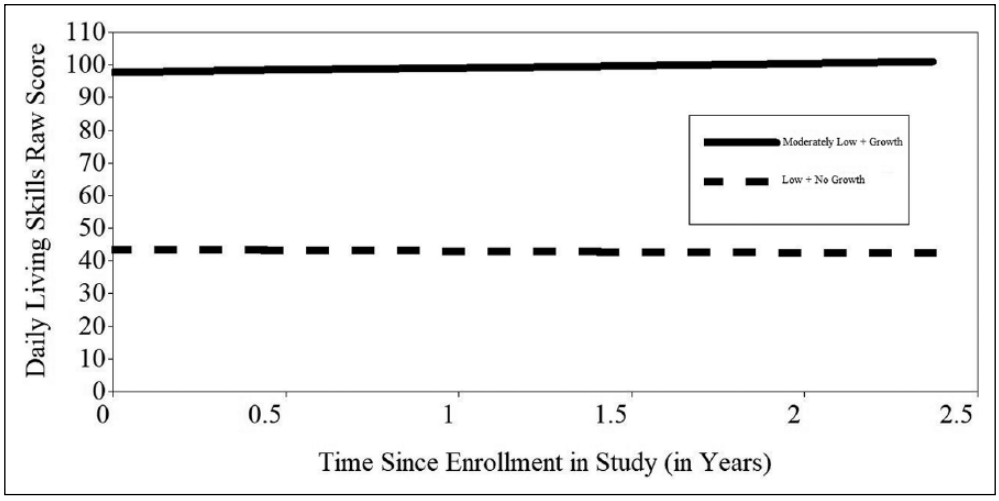

Figure 2. Growth mixture models of daily living skills raw scores.

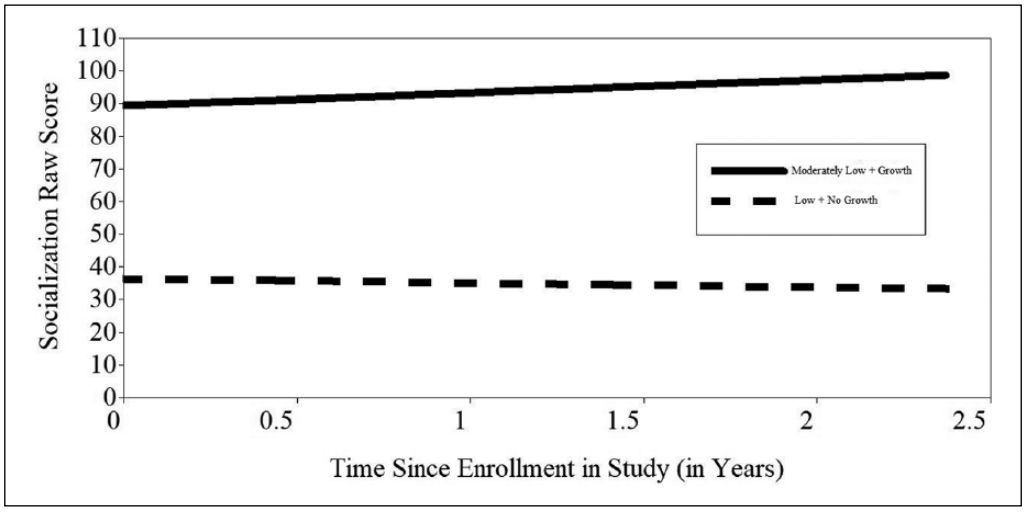

Figure 3. Growth mixture models of socialization raw scores.

Table 7. Group characteristics by adaptive behavior domain.

Predictor	Communication		Daily living skills		Socialization	
	Class 1, % or *M* (*N* = 213)	Class 2, % or *M* (*N* = 31)	Class 1, % or *M* (*N* = 218)	Class 2, % or *M* (*N* = 26)	Class 1, % or *M* (*N* = 200)	Class 2, % or *M* (*N* = 44)
Biological sex (% female)	15.5	13.0	15.1	15.6	14.0	20.6
Age at enrollment	16.3**	17.1	16.3*	17.0	16.3**	16.9
Ethnicity(% nonwhite)	33.1	40.3	33.2	40.7	33.5	36.2
Location (% rural)	11.3	13.0	11.0	15.6	12.0	9.2
Maternal education (% high school or less)	17.5	17.8	17.2	20.7	18.2	14.7
IQ	88.8***	50.2	88.1***	47.7	89.3***	59.2
Autism symptoms						
SCQ	20.9***	26.5	21.0**	26.8	20.5***	26.4
SRS	68.7***	81.0	69.0***	81.3	67.7***	81.9
School quality						
Total	3.21	3.14	3.20	3.20	3.19	3.26
Environment	4.11	3.97	4.10	4.00	4.10	4.08
Climate	3.88	3.88	3.88	3.90	3.86	3.96
Assessment	2.73	2.78	2.72	2.85	2.71	2.87
Instruction	3.10	3.08	3.09	3.13	3.07	3.18
Communication	2.58	2.40	2.57	2.43	2.57	2.52
Social	2.88	2.96	2.87	3.01	2.86	3.03
Independence	2.80*	2.52	2.80*	2.51	2.79	2.66
Functional behavior	2.84	2.58	2.82	2.64	2.82	2.73
Family	3.95	3.73	3.93	3.84	3.91	3.99
Teaming	3.16	3.25	3.15	3.32	3.14	3.32

IQ: intelligent quotient; SCQ: Social Communication Questionnaire; SRS: Social Responsiveness Scale.
Class 1 = moderately low adaptive behavior + growth, Class 2 = low adaptive behavior + no growth. Data represent results from multiple imputation.
*$p < 0.05$. **$p < 0.01$. ***$p < 0.001$.

School quality as a predictor of class membership

Logistic regressions were performed to determine the extent to which school quality predicted class membership. The moderately low adaptive behavior + growth class was set as the reference group. Based on the results of the independent samples *t*-tests, the aspect of school quality that represented differences between classes was selected for a logistic regression. The selected indicator of school quality and parent-reported autism symptoms were included in the models for communication and daily living skills. Age and maternal education were included as covariates. Independence significantly predicted membership into the moderately low adaptive behavior + growth classes for communication and daily living skills controlling for lifelong autism symptoms, age, and maternal education as rated by parents. Individuals with higher independence school quality scores were two times more likely to be in the moderately low adaptive behavior + growth communication class and were two times more likely to be in the moderately low adaptive behavior + growth daily living skills class. Presence of less lifelong autism symptoms significantly predicted membership into the moderately low adaptive behavior + growth communication and daily living skills classes controlling for school quality, age, and maternal education. Younger age significantly predicted membership into the moderately low adaptive behavior + growth class for communication controlling for autism symptoms, school quality, and maternal education (see Table 8).

Discussion

The current study examined teacher-reported adaptive behavior in high school students with ASD. This study identified subgroups of individuals with similar profiles of adaptive behavior changes in communication, daily living skills, and socialization. Phenotypic characteristics and school factors were found to predict developmental trajectories of adaptive behavior for adolescents in this sample. The findings highlight that areas of the school environment, namely, independence, may be an important area for targeted interventions to improve adaptive behavior in high school students with ASD.

Research examining developmental trajectories identifying subgroups of individuals with ASD has mostly been

Table 8. Logistic regression for likelihood of being in the moderately low adaptive behavior + growth class.

Predictor	Communication		Daily living skills	
	B (SE)	Odds ratio	*B* (SE)	Odds ratio
Age	–0.265 (0.132)	0.767*	–0.212 (0.140)	0.809
Maternal education	–0.088 (0.611)	0.916	0.164 (0.6216)	1.18
Autism symptoms	–0.126 (0.041)	0.882**	–0.134 (0.044)	0.874**
School quality				
Independence	0.872 (0.380)	2.39*	0.855 (0.392)	2.35*

SE: standard error; *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

conducted in childhood using parent reports of adaptive behaviors. To our knowledge, this is the first study to examine teacher-reported adaptive behavior during high school in adolescents with ASD. Using GMM, two distinct trajectories of adolescents with ASD were identified for each domain of adaptive behavior. One class of individuals displayed moderately low communication skills, daily living skills, and socialization skills and showed improvement over time, while the other class showed low adaptive behavior skills and no change over time. Across each domain, a majority of individuals with ASD were in the moderately low + growth class. This finding is consistent with the findings of Woodman et al. (2016) in their longitudinal study of individuals with ASD ages 10–52 years, in which they reported two distinct daily living skills trajectories. The second class did display rates of growth in skills over time in daily living skills; however, it was measured over a 10-year period rather than the 2-year period of this study and included a broader age range.

Individuals in the moderately low + growth class gained, on average, 1.85, 1.32, and 3.94 in communication, daily living skills, and socialization skills raw points on the VABS-II, respectively. Based on age-equivalent norms of the VABS-II from ages 14 to 18, adolescents are expected to gain approximately 4 points in communication (average 1 point/year), 4 points in daily living skills (average 1 point/year), and 6 points (average 1.5 points/year) in socialization. Therefore, students in the moderately low + growth class are making significant gains in their skills across 2.5 years. Despite gains in skills in high school, their adaptive behavior standard scores indicate that their adaptive behavior skills remain lower than developmental expectations of their typically developing peers; the average standard scores for the whole sample were below 85 for each adaptive behavior domain across all four time points.

IQ, age at enrollment in the study, and parent and teacher reports of autism symptoms were significantly different between the two groups of adaptive behavior developmental trajectories. Individuals in the moderately low adaptive behavior class and improvement over time had younger ages at enrollment in the study, higher IQs, and lower levels of autism symptoms. These findings are consistent with previous studies reporting a strong association between IQ and adaptive behavior (Baghdadli et al., 2012; Bal et al., 2015; Szatzmari et al., 2015). Autism symptoms have been associated with adaptive behavior in previous research (Baghdadli et al., 2012; Perry et al., 2009), but some studies have reported no relationships (Kanne et al., 2011; Pugliese et al., 2016). The associational findings here may be due to the measures of autism symptoms used, the SCQ and SRS, rather than a diagnostic tool such as the Autism Diagnostic Observation Schedule (ADOS) or Autism Diagnostic Interview—Revised (ADI-R). Studies reporting no findings have included much younger age ranges than this study. Given previous findings of abatement of autism symptoms during adolescence and young adulthood, symptoms in adolescence may be important for adaptive outcomes during this time period (Louwerse et al., 2015; Shattuck et al., 2007; Woodman et al., 2015).

Aspects of school quality significantly predicted class membership above and beyond parent-reported lifelong autism symptoms. Higher independence ratings of school quality were associated with membership in the moderately low and improving communication and daily living skills classes. The independence domain of the APERS examines support and strategies educators employ to support student's self-advocacy, independence in routines and activities, self-management, and planning (Odom et al., 2018). These strategies may be particularly important intervention targets. Independent living is one of the three potential postsecondary goal areas for individualized education plans (IEPs) for students with ASD. Incorporating a focus on these strategies in the IEPs may help promote adaptive behavior skills relevant to postsecondary outcomes.

Since this was the first study to examine the impact of indicators of school quality on adaptive behavior in adolescents with ASD, it was unclear a priori which school quality factors may be significantly related to areas of adaptive behavior. Findings from this study suggest that strategies related to independence may be critical for the development of communication and daily living skills in high school. It was surprising that neither the communication nor social domains of the APERS were related to the communication or socialization adaptive behavior domain. However, these domains had lower program

quality scores in both classes, which may indicate that, in general, schools had lower socialization and communication program quality overall. In addition, post hoc analyses examined the associations among adaptive subdomain standard scores and school quality at Time 1 (Supplement 3). Communication program quality was moderately associated with the communication domain ($r = 0.15$), but not significantly associated with any subdomains. Independence and functional behavior were moderately associated with the communication and daily living skills subdomains ($rs = 0.16–0.25$). Future research may seek to further understand the contributions of school program quality to various aspects of adaptive behavior.

This study is not without its limitations. First, there were missing data across participant characteristics and adaptive behavior. Only a small subset of the sample had adaptive behavior assessed at a fourth time point. Participants with complete data at the fourth time point were younger at the age of enrollment in the study and their mothers had higher education. These variables were included as covariates in the logistic regression models. This study only captured growth over two-and-a-half-year period in high school. Although the age range of the study captured the period of adolescence and early adulthood (14–21), to fully characterize adaptive behavior in high school future research should seek to capture adaptive behavior across 4 years of high school. An additional limitation is that covariates were not included in the GMM and the assigned class membership was used as an outcome variable although classes are latent and classification may be unreliable. However, the entropies of the models are high, which indicates greater confidence in the reliability of the classification (Clark and Muthen, 2009). Finally, this study used parent and teacher reports as measures of autism symptoms rather than diagnostic tools, such as the ADOS. Future research should include an observational measure of autism symptom severity.

Despite these limitations, this study contributes to the literature on adaptive behavior in high school students with ASD in the school context and the impact of school quality on adaptive behavior. In a diverse sample of adolescents with ASD, individuals demonstrated heterogeneity in adaptive behavior. While one group of individuals with ASD began the study with below moderately low to moderately low adaptive behavior scores and showed growth over time, a subset of individuals with ASD entered the study with lower adaptive behavior scores and did not show growth over time. Identifying these students in high school may be relevant for the development of school-based individually targeted interventions focusing on adaptive behavior skills. In addition, both groups had below average adaptive behavior scores across high school. Interventions that focus on improving school quality may play a role in improving adaptive behavior outcomes during the high school years.

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Supplemental material

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