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Regular Article

Trajectories of attention problems in autistic children and relations to social skills outcomes

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Abstract

Co-occurring autism and attention-deficit/hyperactivity disorder (ADHD) have been associated with poorer social skills. Most studies examining the association of ADHD symptoms and social skills in autism employ categorical and cross-sectional designs, which provide a narrow view of the development of ADHD symptoms. Using group-based trajectory modeling, we identified five trajectories of caregiver-reported attention problems in an inception cohort of autistic children ($N = 393$) followed from age 2–5 years (T1) to age 10.5–11 years (T8): Low-Stable (LS; 15.5% of participants), Low-Decreasing (LD; 25.2%), Low-Increasing (LI; 19.2%), Moderate-Decreasing (MD; 32.9%), and High-Stable (HS; 7.2%). Child FSIQ and caregiver age at baseline were lower and caregiver depression at baseline was higher for participants in the MD group than the LS group. Psychotropic medication use was associated with higher attention problems. The MD and HS groups had similar mean Vineland Adaptive Behavior Scales, Second Edition (VABS-II) Socialization standard scores at T8, which were lower than other groups. The LI group had lower Socialization scores than the LS group. Results support that a decline in caregiver-reported attention problems is common but not universal in autistic children and that even moderate/subclinical attention problems may relate to social skills outcomes in autism.

Keywords: Autism; attention problems; social skills; longitudinal

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Introduction

Attention-deficit/hyperactivity disorder (ADHD) is the most common co-occurring neurodevelopmental condition in autistic children, with 40–70% of autistic children also having ADHD (Antshel & Russo, 2019). In contrast, an 8% worldwide prevalence of ADHD in youths was recently reported (Ayano et al., 2023), similar to recent North American general population estimates (8.6% in Canada (Morkem et al., 2020); 10.5% in the United States of America (Danielson et al., 2024)). Among children with ADHD, 12–40% meet criteria for autism diagnosis (Hollingdale et al., 2020). These high rates of co-occurrence are underpinned by potential shared etiological factors, with inattention and hyper-activity/impulsivity constituting possible transdiagnostic markers of these shared factors (Krakowski et al., 2020; Peyre et al., 2021; Rommelse et al., 2010).

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Several studies support that the co-occurrence of autism and ADHD symptoms is associated with greater functional challenges relative to individuals with either autism or ADHD symptoms alone. This is reflected in lower adaptive functioning and quality of life (Sikora et al., 2012; Yerys et al., 2019), more sleep difficulties (Stickley et al., 2021), more problematic eating behavior (Harris et al., 2022), poorer daily executive functioning, and more internalizing and externalizing behavior difficulties (Berenguer et al., 2018; Yerys et al., 2009) compared to individuals with significant autism or ADHD symptoms alone (see Gliga et al. (2018) for evidence of an interaction between autism and ADHD that results in less severe difficulties).

A growing literature is examining social skills, including the ability to pick up and interpret social cues and to demonstrate effective social communication in the context of co-occurring autism and ADHD (Harkins et al., 2021). Differences in social awareness and reciprocity and consequent social difficulties are core diagnostic features of autism. Although this is not the case for ADHD, difficulty socializing with peers is so common in ADHD that it can pose a challenge for the differential diagnosis between autism and ADHD (Rommelse et al., 2018). As such, careful evaluation is required to reveal qualitative differences between social difficulties across these conditions to aid in the diagnosis (Grzadzinski et al., 2016; Mikami et al., 2019).

There is accumulating evidence supporting the idea that children with co-occurring autism and ADHD have poorer social skills and functioning than autistic children without ADHD (e.g., Chiang & Gau, 2016; Factor et al., 2017; Sikora et al., 2012; Yerys et al., 2019; cf. Dellapiazza et al., 2021). Most existing studies of autistic individuals examining the association of ADHD symptoms with social skills have used a categorical approach in analyses; the aim is typically to compare individuals with clinical levels of ADHD symptoms to those below that threshold (e.g., Dellapiazza et al., 2021; Factor et al., 2017; Sikora et al., 2012). Despite its clinical relevance, this approach provides a narrow view of the relation between ADHD symptoms and social skills in autism since subclinical ADHD traits are common in autism (Leyfer et al., 2006) and have been associated with poorer socialization abilities (Yerys et al., 2019).

A further limitation of most studies examining the relation between social skills and ADHD symptoms in autism is the use of a cross-sectional design, neglecting the evolution of ADHD symptoms (e.g., Chiang & Gau, 2016; Factor et al., 2017; Sikora et al., 2012; Yerys et al., 2019). This is particularly problematic since it is well recognized that the severity of ADHD varies over time in the general population (e.g., Murray et al., 2022; Vergunst et al., 2019) and in individuals with ADHD (e.g., Biederman et al., 2010; Biederman, Petty, et al., 2012; Sibley et al., 2022). A focus on cross-sectional designs has resulted in limited knowledge about the persistence or remission of ADHD symptoms in autism and of factors that might be related to ADHD symptom trajectories. Moreover, whereas longitudinal studies of ADHD symptoms often separate inattention and hyperactivity/impulsivity symptoms, partly because it has been established that these symptom domains follow distinct trajectories (Arnold et al., 2014; Vergunst et al., 2019), cross-sectional studies of ADHD symptoms in autism often combine these symptom domains. Because of this approach, there is limited understanding of the association of each symptom domain with social skills in autism (e.g., Dellapiazza et al., 2021; Factor et al., 2017; Yerys et al., 2019).

Only three previous studies have investigated multiple trajectories of ADHD symptoms in autistic individuals; they separately examined attention problems (McCauley et al., 2020; Visser et al., 2017) or hyperactivity (Anderson et al., 2011). These studies are summarized in Table A1 of the appendix. The study samples were largely but not exclusively composed of individuals who met diagnostic criteria for Autism Spectrum Disorder (ASD), and only one examined the association of ADHD symptom trajectories—attention problems specifically—with social outcomes (McCauley et al., 2020). These studies suggest that decreasing attention problems and hyperactivity are common in autism. Visser et al. (2017) found that clinical levels of attention problems are rare in autistic preschoolers followed until a mean age of 5.6 years. In particular, they found that the mean Attention Problems (AP) standard scores of the Child Behavior Checklist for Ages 1½–5 (CBCL 1.5–5) remained in the moderate/borderline (i.e., standard score between 60 and 70) or subclinical range across the four trajectory groups they identified, namely Moderate-Decreasing (48% of participants), Moderate-Stable (22%), Low-Increasing (20%), and Low-Stable (5%). McCauley et al. (2020) found that clinical levels of attention problems are rare in later childhood to early adulthood (i.e., from a mean age of 9.4 years to a mean age of 25.7 years). They identified a High-Decreasing group (41% of participants) with mean CBCL AP standard score at baseline in the clinical range (i.e., >70) which declined to the moderate/borderline range by young adulthood. The mean AP score of the Low-Decreasing group (59%) was below the clinical range across all study assessment points. The clinical level of hyperactivity scores was not reported in Anderson et al. (2011) who identified four trajectories of Hyperactivity raw scores from the Aberrant Behavior Checklist in a sample of children who were followed until late adolescence. Trajectory groups were characterized by low-decreasing (44% of participants), moderate-decreasing (36%), high-decreasing (11%), or lowest-decreasing (9%) Hyperactivity scores.

In terms of attention problems —the focus of the current study — longitudinal studies of the general population reveal that in contrast to what has been described in autistic samples to date, the vast majority of individuals follow trajectories characterized by low attention problems that remain stable or decline slightly across childhood to adolescence (e.g., Döpfner et al., 2015; Murray et al., 2020; Riglin et al., 2016; Robbers et al., 2011). Moreover, general population studies suggest that few experience persistently high attention problems in childhood, consistent with a subset of the population having ADHD (Murray et al., 2020; Pingault et al., 2011; Riglin et al., 2016; Vergunst et al., 2019). Neither Visser et al. (2017) nor McCauley et al. (2020) identified such a trajectory. This may be due to the age range of participants in those studies. In particular, general population studies found that attention problems increase over the preschool years among those who go on to have persistently high symptoms in childhood (Riglin et al., 2016; Vergunst et al., 2019) and that this group shows a decrease by adolescence (Riglin et al., 2016). Moreover, there is a trend in ADHD for attention problems to decline in older adolescence/young adulthood (Lahey et al., 2016; Vos et al., 2021).

In terms of factors associated with attention problems, McCauley et al. (2020) found that participants referred for autism diagnosis who had more severe attention problems had lower adaptive skills at ages 2, 5, and 9 years compared to those with low attention problems. Groups did not differ on childhood verbal IQ or severity of autism symptoms. In general population studies, male sex assigned at birth and lower IQ have been associated with more severe inattention and combined inattention and hyperactivity/impulsivity symptoms of ADHD (e.g., Riglin et al., 2016; Vergunst et al., 2019). In terms of family or caregiver variables, lower socioeconomic status, younger maternal age, and parental depression have been associated with more severe attention problems in children (Döpfner et al., 2015; Vergunst et al., 2019).

McCauley et al. (2020) found that the association of attention problems trajectories and functional outcomes in autistic individuals varied across cognitive ability groups. Among autistic adults with higher verbal IQ (VIQ ≥ 70), those in the High Decreasing AP class achieved fewer positive adult outcomes, including living independently, being employed, and having at least one true friend, than those in the Low Decreasing class. In contrast, in autistic adults with VIQ<70, trajectories of AP standard scores were not associated with the number of positive outcomes achieved by adulthood, suggesting that behaviors suggestive of attention problems were a less important determinant of adult outcomes in that group compared to the group without cognitive disability.

Present study

Our first aim was to describe the trajectories of caregiver-reported attention problems as defined by the CBCL AP scale in an inception cohort of children diagnosed with ASD between the ages

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Table 1. Assessment schedule for the pathways in ASD study

Child age at diagnosis	T1	T2 *6 months after T1*	T3 *6 months after T2*	T4 = Age 6 assessment *24 months after T1*	 *36 months after T1*	 *48 months after T1*	T5 = Age 7 – 8.5 assessment	T6 *12 months after T5*	T7 *12 months after T6*	T8 *12 months after T7*
2 years old	X	X	X			X	X	X	X	X
3 years old	X	X	X		X		X	X	X	X
4 years old	X	X	X	X			X	X	X	X

of 2 and 4 years, 11 months and followed from within four months of their diagnosis (i.e., age 2 to 5 years) until age 10.5 to 11 years. This extends findings from a previous study by our group that examined the average trajectory of caregiver-reported attention problems in the same autistic sample relative to the general population and found that, on average, children diagnosed with ASD at a young age show a decline in attention problems (Wright et al., 2023). It is likely that the average trajectory identified by Wright et al. (2023) is in fact a reflection of multiple trajectories, not all of which involve decreasing attention problems. Based on the findings by Visser et al. (2017), the high rate of co-occurrence of autism and ADHD (Antshel & Russo, 2019; Hollingdale et al., 2020), and evidence that a subset of individuals with ADHD have persistent ADHD symptoms from childhood into young adulthood (Sibley et al., 2022), we predicted that we would identify at least four trajectory groups: one characterized by stable low to moderate caregiver-reported attention problems over time, one with decreasing attention problems, one with increasing attention problems, and another with stable elevated attention problems.

Our second aim was to investigate the association between child and family baseline characteristics and caregiver-reported attention problems trajectories within our autistic cohort. We selected child and family characteristics based on previous literature supporting their association with ADHD symptom severity and their availability in our data. We predicted that more severe autism symptoms, lower child IQ, higher socioeconomic risk, younger primary caregiver age, and greater primary caregiver depression symptoms would be associated with membership in the trajectory(ies) with more severe or increasing attention problems (Anderson et al., 2011; Vergunst et al., 2019; Wright et al., 2023). For descriptive purposes, we examined the rates of use of psychotropic medications, including ADHD medications, and 'soft psychotropics' (i.e., substances that can be purchased without a physician's prescription and have purported psychotropic effects) across the trajectory groups. We predicted that their use would be associated with more severe attention problems.

Our third aim was to examine the association of caregiver-reported attention problems trajectories with social abilities in late childhood. We predicted that groups with initial or later elevated attention problems would have lower socialization skills compared to children with less pronounced attention problems.

Methods

Participants

The Pathways in ASD study is a Canadian multi-site longitudinal study examining the developmental trajectories of children diagnosed with ASD. A cohort of 421 newly diagnosed autistic preschoolers and their primary caregivers was recruited from five autism referral centers across Canada (Halifax, Montreal, Hamilton, Edmonton, Vancouver) . The study was approved by the Research Ethics Boards at each site. Informed consent was obtained from all participating families.

Eligible children met diagnostic criteria for ASD according to assessment by an experienced clinician or multidisciplinary team using Diagnostic and Statistical Manual of Mental Disorders-Fourth Edition (DSM-IV) criteria. Diagnoses were confirmed for research with the Autism Diagnostic Observation Schedule (ADOS; Lord et al., 2001) and Autism Diagnostic Interview-Revised (ADI-R; Rutter et al., 2003). Children with neuromotor disorders that might interfere with study assessments, known genetic or chromosomal abnormalities at baseline, and severe visual or hearing impairments were ineligible. Only one child per family was recruited to ensure independence of observations.

For the current study, data from baseline (T1) to time point 8 (T8) were analyzed. Baseline data were collected between 2005 and 2011. At T1, children were between 2 and 5 years old and within 4 months of having received an ASD diagnosis ($N = 411$; $M_{age} = 40.2$ months; $SD = 9.3$). Table 1 displays the assessment schedule based on child age at time of ASD diagnosis. It shows that baseline, T2, and T3 assessments were conducted at 6-month intervals. T4 assessments were conducted when children were around 6 years old. All subsequent assessments were conducted at 12-month intervals. At T8, children were 10.5 to 11 years old ($n = 281$; $M_{age} = 10.7$ years; $SD = 0.2$).

Measures

Children's level of caregiver-reported attention problems was represented by total raw scores on the AP scales of the CBCL 1.5–5 and CBCL 6–18 Parent Forms (Achenbach & Rescorla, 2000, 2001). These empirically derived scales were used rather than the DSM-oriented Attention Deficit/Hyperactivity Problems scales because of evidence that both scales have similar, good correspondence to a diagnosis of ADHD (Ebesutani et al., 2010; Gomez et al., 2021), as well as the prominent use of the AP scale in studies of ADHD symptoms, including in samples of autistic individuals (e.g., McCauley et al., 2020; Visser et al., 2017). The CBCL 1.5–5 AP scale has five items (*can't concentrate, can't sit still, clumsy, shifts quickly, wanders*) and that from the CBCL 6–18 has 10 items (*acts young, fails to finish, can't concentrate, can't sit still, confused, daydreams, impulsive, poor school, inattentive, stares*). Each item is rated from 0 to 2 (0 = *Not True (as far as you know)*; 1 = *Somewhat or Sometimes True;* 2 = *Very True or Often True*). The CBCL has commonly been used in autistic children (e.g., Vaillancourt et al., 2017) and has been found to have good reliability and validity in this population (Pandolfi et al., 2009, 2012).

From T1 to T4, the CBCL 1.5–5 was administered whereas from T5 to T8, the CBCL 6–18 was administered. Although changing scales is necessary to appropriately measure constructs whose behavioral expression change with development, this change in scales must be accounted for in analyses to ensure that score changes reflect change in the level of the construct (Petersen et al., 2020). To address changing scales, we transformed raw scores on the CBCL AP scale to percentage scores by dividing the raw score by the total possible raw score for the scale, such that the AP scales for each CBCL version had the same possible range. In addition, we evaluated evidence for the stability in function and meaning of the AP scales from the CBCL 1.5–5 and 6–18, based on the six criteria specified by Petersen et al. (2020). These criteria are (1) the content selected for the measures reflects the same construct based on theory and adequately samples different facets of the construct (content validity); (2) good short-term test-retest reliability of the measures' scores; (3) the measures' scores show convergent validity, as well as divergent validity with measures of other constructs; (4) scores of each measure have a similar but not necessarily invariant factor structure across time; (5) scores have high internal consistency; (6) scores are sensitive to change and show theoretically expected developmental change. See Appendix for evidence supporting these criteria.

Autism symptom severity at baseline was represented by the ADOS Social Affect (ADOS SA-CSS) and Restricted and Repetitive Behaviors (ADOS RRB-CSS) calibrated severity scores (Hus et al., 2014). These scores are adjusted for the child's age and language skills. The ADOS calibrated severity scores have been found to be only weakly associated with CBCL Externalizing and Internalizing T-scores and comorbid psychiatric classifications, including ADHD, supporting discriminant validity (Bal & Lord, 2015; Louwerse et al., 2015).

Child full-scale IQ (FSIQ) at T1 was represented by the Developmental Index of the Merrill-Palmer-Revised Scales of Development (M-P-R; Roid & Sampers, 2004) or the full-scale IQ estimate from the Wechsler Preschool and Primary Scale of Intelligence-III (WPPSI-III; Wechsler, 2002). The M-P-R relies minimally on children's language skills; it does not include a measure of expressive language skills within the global intellectual ability scale. The WPPSI-III was administered as an additional measure to children who reached ceiling on the M-P-R. For children of low ability for whom a standard score could not be obtained on the M-P-R, a score one point lower than the lowest possible standard score for their age was assigned (Flanagan et al., 2015). By using baseline IQ, we inform how factors at the time of autism diagnosis are related to trajectories of caregiver-reported attention problems.

Communication ability at T1 was assessed using the Vineland Adaptive Behavior Scales, Second Edition (VABS-II) Communication standard score (Sparrow et al., 2005). The VABS-II is a semi-structured interview administered to primary caregivers. The Communication domain score assesses receptive, expressive, and written communication skills in everyday life. The VABS-II has sound concurrent validity and reliability (Sparrow et al., 2005). It has commonly been used in studies of autistic individuals (e.g., Haviland et al., 2011; McCauley et al., 2020; Visser et al., 2017).

Socioeconomic risk (SER) at baseline was indexed through four indicators coded as 1 to indicate higher risk and 0 to indicate lower risk, as in Zaidman-Zait et al. (2021). The indicators were (1) lone parent household (divorced, widowed, single, legally separated = 1; married/common-law = 0), (2) primary caregiver education (no degree beyond high school = 1; obtained a college, trade school or university degree = 0), (3) caregiver immigration status (both parents born outside Canada = 1; not so = 0), and (4) annual household income (≤$40,000 CAD = 1; >$40,000 CAD = 0). The indicators were selected based on Canadian data supporting their relevance to childhood poverty (Campaign, 2000, 2015) and were measured using the Family Background Information Questionnaire, a caregiver-completed demographic questionnaire, purpose-built for the Pathways in ASD study.

Primary caregivers' depression symptoms were assessed using the Symptom Checklist-90-R (SCL-90-R; Derogatis, 1994), a self-report checklist designed to evaluate psychological problems and symptoms of psychopathology in adults. In the current study, we used the Depression scale t-score representing caregivers' level of depression symptoms relative to a non-clinical normative sample of adults and accounting for caregiver sex. Primary caregivers responded on a 5-point Likert scale, ranging from 0 = *not at all* to 4 = *extremely*. The Depression scale of the SCL-90-R has been found to have good concurrent validity with the Beck Depression Inventory and similar sensitivity and specificity as the Beck Depression Inventory for identifying depression in psychiatric outpatients (e.g., Kostaras et al., 2020; Prinz et al., 2013). It has previously been found to have good internal consistency (Derogatis, 1994).

Children's psychotropic medication use was assessed at each time point through the caregiver-completed General Health Questionnaire developed for the Pathways in ASD study. Caregivers were requested to list all prescription and non-prescription medications their children were taking at each time point. Psychotropic medications were defined as medications capable of affecting cognition, mood, and behavior and included antidepressants, mood stabilizers, anxiolytics, anti-psychotics, alpha-agonists, anti-seizure medications, and psychostimulants. A list of the psychotropic medications reported by caregivers is included in Table A2 of the Appendix. We also identified ADHD medications as a sub-category of psychotropic medications, including, amphetamine/dextroamphetamine, atomoxetine, dextroamphetamin, guanfacine, lisdexamfetamine, and methylphenidate. Moreover, we identified "soft psychotropics" (e.g., melatonin, oxytocin), the coding of which is detailed in the Appendix (Tables A3 and A4).

The VABS-II Socialization standard score at T8 was used as a measure of social skills. This scale assesses interpersonal relationships, social play and leisure skills, and social coping.

Missing data

Excluding data from four participants who were found to be ineligible for the Pathways in ASD study after recruitment (see Appendix for details), three who withdrew from the study and requested that their data be removed, and 21 participants who had missing AP scores at all eight time points, resulted in a sample of 393 children with ASD at T1 for the current analyses. Participants excluded because of missing CBCL data and those retained did not differ significantly with respect to baseline FSIQ, ADOS RRB-CSS, VABS-II Communication standard score, socioeconomic risk, caregiver age, caregiver employment status, psychotropic medication, ADHD medication, or soft psychotropic use, $p > .05$. Excluded participants had lower ADOS SA-CSS compared to those without missing data ($t(16.27) = -3.00$, $p = .008$). There was only one participant with an SCL-90-R Depression score that was excluded from the current analyses because of missing CBCL data.

Of the retained participants, 270 (69%) had AP scores at four or more time points (11, 10, 13, 13, 22% with data at four, five, six, seven, and eight time points, respectively). At T8, CBCL AP scores

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were available for 174 (44%) participants (T1: $n = 361$ (92%); T2: $n = 325$ (83%); T3: $n = 299$ (76%); T4: $n = 249$ (63%); T5: $n = 197$ (50%); T6: $n = 209$ (53%); T7: $n = 157$ (40%)).

Analyses examining the association of missingness of AP scores at each time point with this study's analysis variables and variables previously found to be associated with attrition in the Pathways in ASD study, revealed associations of missingness with later AP scores, child FSIQ, ADOS RRB-CSS, communication skills, socioeconomic risk, age of primary caregiver, and caregiver depression symptoms (Appendix).

In terms of VABS-II Socialization scores, none of the participants who were excluded because of missing CBCL data had VABS-II data at T8. Of the 393 participants who were included in the current analyses, 176 (45%) had missing VABS-II Socialization scores at T8. These participants had lower communication skills at baseline than those with VABS-II Socialization scores at T8 ($p = .02$). There were no significant differences between groups in terms of baseline autism symptom severity, child FSIQ, family socioeconomic risk, or caregiver depression symptoms. Table A5 of the Appendix delineates the extent of missing data per variable.

Analytic plan

Trajectory groups for CBCL AP scores across the eight time points were derived using PROC TRAJ in SAS software, Version 9.4 of the SAS System for Windows (Copyright © 2016 by SAS Institute Inc., Cary, NC, USA). PROC TRAJ applies a semi-parametric group-based trajectory modeling (GBTM) approach that identifies clusters of participants from the entire sample that share similar trajectories (Jones et al., 2001; Jones & Nagin, 2007). PROC TRAJ uses a maximum likelihood estimation approach to derive the parameter estimates that define the group sizes and the shapes of trajectories. Thus, participants with missing data are included in the analyses and models are estimated using all available information. This approach assumes that data are missing at random (MAR; i.e., missingness is related to variables that are included in the analyses). The potential impact of nonrandom missingness on trajectories is evaluated as part of the analysis steps described below.

Models were fit using a beta distribution suitable for continuous data that are not normally distributed (Elmer et al., 2018). This produced better fitting models —based on Bayesian Information Criterion (BIC) values— than using the censored normal distribution or the Poisson distribution. To use the beta distribution, CBCL AP proportion scores were transformed to a 0 to 1 scale.

Trajectories were allowed to vary in their intercepts and slopes with respect to time. First, unconditional models with 1 to 7 groups were compared using the BIC, calculated with $N =$ number of participants (i.e., 393) and $N =$ total number of observations (i.e., 1971), with the theoretically correct BIC falling between these values (Nagin, 2005). The magnitude of the Bayes factor approximated by $e^{BICi\text{-}BICj}$ (Kass & Raftery, 1995; Schwarz, 1978) was evaluated against the criteria proposed by Wasserman (2000). In addition, the log Bayes factor approximated by $2^*(BIC_i - BIC_j)$ was evaluated against the criteria specified by Jones et al. (2001). Model fit adequacy was evaluated using the following criteria: the average posterior probability of group membership for each group was greater than 0.70 and the Odds of Correct Classification for each group was greater than 5 (Nagin, 2005). Moreover, we considered model parsimony as well as the width of confidence intervals around model estimates. Once the optimal number of trajectories was determined, we compared models with linear, quadratic, cubic, and stable slopes to identify the model that best fit the data. Trajectory groups were characterized by comparing their intercepts and slopes using Wald tests.

The selected model was then extended to account for the possibility of nonrandom dropout, which is defined as occurring at the time that no further AP scores are available for each participant (Haviland et al., 2011). This extension jointly estimates trajectories of the outcome variable (i.e., AP scores) and the probability of dropout for each trajectory group. Using p-values of the parameter estimates in the dropout model, we explored whether the probability of dropout would be most accurately modeled as constant, dependent on the previous observed AP score, or dependent on the previous two observed AP scores (B. Jones, personal communication, February 17, 2023). Variables found to be associated with missingness of AP scores (i.e., baseline FSIQ, ADOS SA-CSS and RRB-CSS, communication skills, socioeconomic risk, caregiver age, caregiver depression) were included as covariates in the dropout model.

We then used PROC TRAJ to examine the association of trajectory group membership with baseline variables —ADOS SA-CSS and RRB-CSS, FSIQ, socioeconomic risk, age of primary caregiver, and caregiver depression symptoms. We also examined the relation of psychotropic medications, ADHD medications specifically, and soft psychotropics with level of caregiver-reported attention problems within each trajectory group. This was done by including time-variant, dichotomous (yes/no) indicators of use of psychotropic medications or soft psychotropics as covariates in the GBTM model. We used chi-square analyses to compare the proportion of participants reportedly using psychotropic medications, ADHD medications specifically, or soft psychotropics at one or more time points across trajectory groups.

We used PROC TRAJ to compare the identified AP trajectory groups on VABS Socialization standard scores at T8. This approach accounts for uncertainty in group membership. In addition, as a sensitivity analysis, we used analysis of covariance (ANCOVA) to examine the association of group membership with T8 Socialization standard scores within multiply imputed datasets. The maximum-probability assignment rule was used, which places each participant into the group to which their posterior membership probability is largest. We aimed to control for baseline child SA and RRB symptom severity, FSIQ, and communication skills, given their previously reported association with social skills (Ben-Itzchak et al., 2019; Zaidman-Zait et al., 2021), however, we did not include communication skills or FSIQ as covariates because of significant differences between our derived trajectory groups on these variables ($p < .001$ and $p = .008$, respectively; see Table A9 of Appendix) (Miller & Chapman, 2001). Details of the imputation and pooling of data are described in the Appendix. Throughout the analyses, we applied Benjamini-Hochberg corrections for multiple comparisons (Benjamini & Hochberg, 1995).

Results

Baseline demographic and clinical characteristics of the 393 participants included in the current analyses are presented in Table 2.

Based on model fit, adequacy indices, and clinical relevance (Tables A6 and A7; Figure A1), a five-group model with linear slopes was selected. The dropout function was then added to the model. No parameter estimates for an association of dropout (i.e.,

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Table 2. Baseline demographic and clinical characteristics

Variable	Values
Age in months *M* (*SD*)	40.91 (9.30)
Min – Max	23.80–63.39
Sex assigned at birth	330 Male: 63 Female
FSIQ[a] *M* (*SD*)	50.96 (28.71)
Min – Max, % FSIQ < 70	9–136, 76.3%
VABS Communication standard score *M* (*SD*)	73.46 (15.93)
Min – Max	40–118
ADOS SA-CSS *M* (*SD*)	7.43 (1.85)
Min – Max	2–10
ADOS RRB-CSS *M* (*SD*)	7.85 (1.71)
Min – Max	1–10
Number of socioeconomic risk factors	
0	145
1	117
2	60
3	19
4[b]	2
CBCL AP standard scores *M* (*SD*), Min – Max	60.50 (8.50), 50 – 80

Note. ADOS RRB-CSS = Restricted and Repetitive Behaviors calibrated severity score of the Autism Diagnostic Observation Schedule; ADOS SA-CSS = Social Affect calibrated severity score of the ADOS; CBCL AP = Attention Problems scale of the Child Behavior Checklist; FSIQ = Full-Scale Intelligence Quotient; *M* = Mean; *SD* = standard deviation.
[a]IQ scores for 324 participants (86.4%) were from the M-P-R. Three participants' (0.8%) IQ scores were from the WPPSI-III. IQ scores for 48 participants (12.8%) were imputed as one score lower than the lowest possible score for their age on the M-P-R, due to their failure to reach basal on that measure.
[b]Participants with three and four socioeconomic risk factors were combined in the analyses due to the low number of participants with four risk factors.

missingness of AP scores) with the previous one or two AP scores were significant (when applying Benjamini-Hochberg corrections; Benjamini & Hochberg, 1995). Therefore, dropout was modeled as constant. None of the variables associated with missing AP scores (i.e., child FSIQ, autism symptom severity and communication skills at baseline, socioeconomic risk, age of primary caregiver, and caregiver depression) were significantly associated with dropout in any group. Therefore, to reduce the number of parameter estimates we did not include covariates of dropout in the models. The selected five-group model is displayed in Figure 1.

Based on intercepts and slopes and the mean CBCL AP standard scores at T1, we labeled the trajectory groups "Low-Stable" (Group 1; 15.5%), "Low-Increasing" (Group 2; 19%), "Low-Decreasing" (Group 3; 25%), "Moderate-Decreasing" (Group 4; 33%), and "High-Stable" (Group 5; 7%). As seen in Table 3, intercepts were significantly different between groups except for the Low-Increasing and Low-Decreasing groups. Slopes of the Low-Decreasing and Moderate-Decreasing groups were not significantly different from one another.

Given the relatively large number of baseline covariates of interest, to reduce the number of parameters in the model, we identified baseline covariates that were individually significantly associated with group membership (i.e., $p \leq .05$) and then entered this select set of covariates in the model. Table 4 shows log-odds estimates for the association of these select baseline covariates with membership in each trajectory group relative to the Low-Stable trajectory group (Nagin, 2005). Applying Benjamini-Hochberg corrections, lower child FSIQ, younger age of the primary caregiver, and more severe caregiver depression symptoms at baseline were significantly associated with an increased likelihood of belonging to the Moderate-Decreasing group compared to the Low-Stable group.

Table A8 shows the rate of use of psychotropic medications, ADHD medications specifically, and soft psychotropics across trajectory groups and time points, ranging from 1.4 to 63.6% of the sample for psychotropic medications, 0 to 50% for ADHD medications, and from 6.5 to 42.1% for soft psychotropics. There was a significantly higher likelihood of use of psychotropic medications in trajectory groups with more severe caregiver-reported attention problems ($\chi^2(4) = 18.86$, $p < .001$). A similar effect was observed for ADHD medications ($\chi^2(4) = 11.45$, $p = .02$). In addition, we found that within the Low-Stable and Moderate-Decreasing trajectory groups, taking psychotropic medication was associated with higher caregiver-reported attention problems ($p \leq .001$ for the Low-Stable trajectory group; $p = .003$ for the Moderate-Decreasing trajectory group). Wald tests indicated that the strength of the association was greater in the Low-Stable trajectory group than in the other four groups (all p's < .005); the strength of association in the Moderate-Decreasing group did not significantly differ from that in the Low-Increasing, Low-Decreasing, or High-Stable groups. Use of ADHD medications and soft psychotropics was not significantly associated with caregiver-reported attention problems within any trajectory group.

Figure 2 displays the mean VABS Socialization standard scores of each trajectory group. Based on 95% confidence intervals, the High-Stable and Moderate-Decreasing groups had lower socialization skills at T8 compared to the other three groups and were not significantly different from each other. The Low-Increasing group had lower mean socialization skills than the Low-Stable group, with the Low-Decreasing group between them and not significantly different from either. ANCOVA performed as a sensitivity analysis corroborated the above findings (Appendix).

Discussion

We identified five trajectories of caregiver-reported attention problems in an inception cohort of autistic children followed from within four months of diagnosis as a preschooler until pre-adolescence (age 10.5–11 years). Over half of the sample (58.1%) followed a declining trajectory of attention problems—25.2% with a low-decreasing trajectory and 32.9% with a moderate-decreasing trajectory. The next most common trajectory pattern was stable attention problems, with 15.5% of participants following a low-stable trajectory and 7% following a high-stable trajectory. The latter had a clinical level of attention problems as assessed by the CBCL. In addition, we found that an important minority of children (19.2%) was characterized by low-increasing attention problems.

The current study and previous studies in autism support that attention problems trajectories are heterogeneous in autism and are distinct from the general population and individuals with ADHD. Consistent with previous trajectory studies in autistic individuals (McCauley et al., 2020; Visser et al., 2017), we found that few autistic children followed a low-stable trajectory of attention problems. Moreover, the rate of persistently high attention problems in the current study is greater than what has been reported in general population studies (Murray et al., 2020; Riglin et al., 2016) but less than what is suggested by studies of children with ADHD (Arnold et al., 2014; Sasser et al., 2016). This

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Table 3. Trajectory group parameters

Model elements	Low-Stable	Low-Increasing	Low-Decreasing	Moderate-Decreasing	High-Stable
Intercepts					
Estimate (SE)	−1.65 (0.08)	−0.79 (0.02)	−0.39 (0.02)	0.54 (0.11)	1.13 (0.11)
Comparisons	LS vs LI	LI vs LD	LD vs MD	MD vs HS	
χ^2 (df)	24.69 (1)	3.06 (1)	25.57 (1)	15.25 (1)	
p	< **.001**	.08	< **.001**	< **.001**	
Slopes					
Estimate (SE)	–	0.12 (0.02)	−0.11 (0.02)	−0.08 (0.02)	–
Comparisons			LD vs MD		
χ^2 (df)			0.90 (1)		
p			.34		

Note. HS = High-Stable trajectory group; LD = Low-Decreasing trajectory group; LI = Low-Increasing trajectory group; LS = Low-Stable trajectory group; MD = Moderate-Decreasing trajectory group; SE = Standard Error.

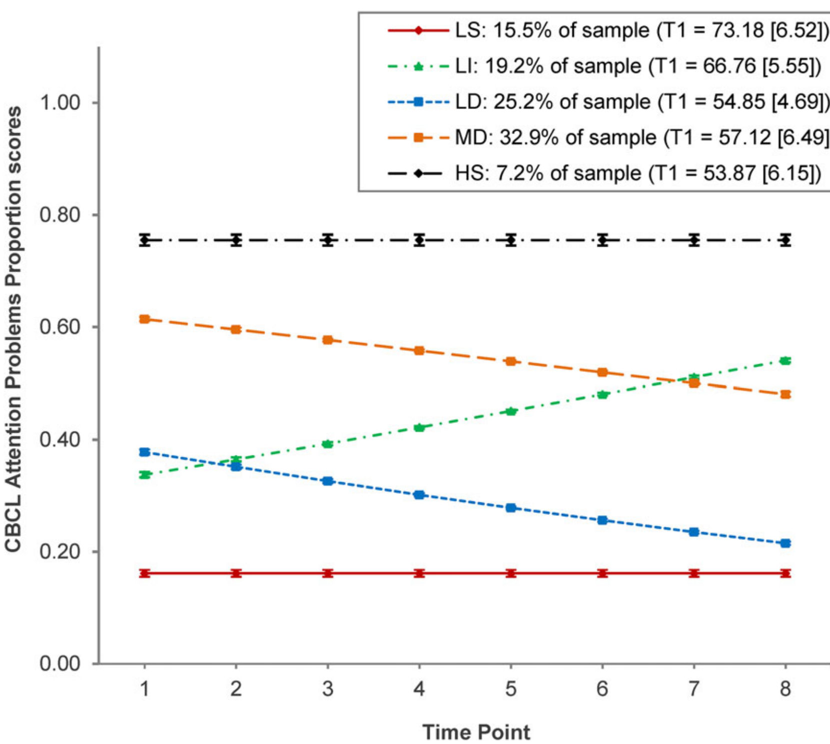

Figure 1. Group-based trajectories of proportion raw scores of the CBCL attention problems scales. Error bars delineate limits of 95% confidence intervals. Dropout is accounted for in the model. T-scores in the figure legend represent each trajectory group's mean CBCL Attention Problems standard score (standard deviation) at T1 based only on available data ($n = 361$). CBCL = Child Behaviour Checklist; HS = High-Stable; LD = Low-Decreasing; LI = Low-Increasing; LS = Low-Stable; MD = Moderate-Decreasing.

pattern is expected based on the high rate of co-occurrence of autism and ADHD and aligns with evidence that autistic children, on average, have higher levels of attention problems than the general population (Wright et al., 2023). The presence of a High-Stable trajectory in the current study but not in previous trajectory studies of younger (Visser et al., 2017) or older (McCauley et al., 2020) autistic individuals raises the possibility that, as has been reported in the general population and consistent with ADHD studies, individuals with persistently high attention problems in childhood show an increase in the preschool years and then a decline in adolescence/young adulthood (Riglin et al., 2016; Sasser et al., 2016; Vergunst et al., 2019).

Despite the overall higher rate of attention problems in autistic children than in the general population, it is promising that converging evidence supports that autistic children tend to have declining attention problems. In particular, the prominence of declining trajectories in the current study (58.1% of the sample), combined with findings from two previous trajectory studies in autism (McCauley et al., 2020; Visser et al., 2017), supports that the most common trajectory of attention problems in autism from early childhood to young adulthood is declining. This is consistent with evidence that the average trajectory of caregiver-reported attention problems in autism is declining (Wright et al., 2023).

Consistent with Visser et al. (2017) and in contrast to McCauley et al. (2020), a minority of autistic children in the current study had increasing caregiver-reported attention problems. It is reassuring that the prevalence of this trajectory is similar to that reported in general population studies following children across a similar age

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Table 4. Parameters of association between baseline covariates and trajectory group membership relative to membership in the low-stable group

Trajectory group compared to Low-Stable group	Coefficient	SE	Test statistic (t)	*p*
Low-Increasing trajectory group				
Social Affect symptom severity	−0.05	0.12	−0.38	.70
FSIQ	−0.01	0.01	−0.99	.32
Caregiver age	−0.003	0.003	−0.91	.36
SER	0.52	0.28	1.86	.06
SCL-90-R Depression	−0.01	0.02	−0.56	.57
Low-Decreasing trajectory group				
Social Affect symptom severity	0.16	0.11	1.46	.14
FSIQ	−0.01	0.01	−1.27	.20
Caregiver age	−0.003	0.003	−1.01	.31
SER	0.54	0.25	2.16	.03
SCL-90-R Depression	0.05	0.02	2.35	.02
Moderate-Decreasing				
Social Affect symptom severity	0.07	0.16	0.42	.67
FSIQ	**−0.04**	**0.01**	**−3.12**	**.002**
Caregiver age	**−0.02**	**0.01**	**−2.79**	**.005**
SER	0.43	0.33	1.31	.19
SCL-90-R Depression	**0.11**	**0.04**	**2.95**	**.003**
High-Stable trajectory group				
Social Affect symptom severity	0.36	0.24	1.52	.13
FSIQ	0.01	0.01	0.90	.37
Caregiver age	0.01	0.01	1.69	.09
SER	0.50	0.47	1.08	.28
SCL-90-R Depression	0.03	0.04	0.68	.49

Note. Benjamini-Hochberg corrections were applied to identified significant associations. SCL-90-R = Symptom Checklist-90-R; SE = Standard Error; SER = Socio-Economic Risk.

range as the current study (Pingault et al., 2011; Robbers et al., 2011; Vergunst et al., 2019). This suggests that increasing attention problems do not occur more frequently in autism than in the general population. This trajectory does not necessarily represent worsening attention problems but likely reflects a delay in development of attention abilities such that increasing apparent severity of attention problems may indicate that an individual's internal (e.g., high cognitive ability) or external compensatory mechanisms (e.g., school or family support) are not sufficient to meet increasing demands with age (e.g., academic demands, peer interaction demands) (Murray et al., 2020).

Regarding the relation between baseline variables and caregiver-reported attention problems, we found a significant association of lower child FSIQ, younger age of caregivers, and higher caregiver depression with membership in the Moderate-Decreasing trajectory group relative to the Low-Stable group. With respect to child FSIQ, we found that for each one-point increase in IQ, the odds of being assigned to the Moderate-Decreasing group were 0.96 times the odds of being in the Low-Stable group (i.e., the odds of assignment to the Moderate-Decreasing group were lower with increasing FSIQ). The relation between ADHD symptoms and IQ is inconsistent across studies, both in the general population and in autistic individuals. Some studies find an association of lower IQ with more severe ADHD symptoms (Simonoff et al., 2013; Vergunst et al., 2019; Wright et al., 2023) whereas others do not (Øie et al., 2023; Dellapiazza et al., 2021; McCauley et al., 2020; Murray et al., 2022). Inconsistency in results across studies may partly reflect differences in the level of IQ of the samples and age at which IQ was assessed since developmental change and greater variability is expected in level of intellectual functioning as represented by IQ scores across early childhood, especially for toddlers with mild to moderate cognitive delays (Flanagan et al., 2015; Prigge et al., 2022; Solomon et al., 2018). In addition, when significant associations are reported, they are of small magnitude, supporting that IQ is of limited prognostic significance for attention problems characteristic of ADHD and likely contributing to inconsistent findings across studies. Indeed, previous studies have found that ADHD generally has a limited relation with IQ (Biederman, Fried, et al., 2012; Jepsen et al., 2009). This is supported by our finding that the trajectory group with most severe caregiver-reported attention problems (i.e., High-Stable group) did not have the lowest mean FSIQ.

A one-year increase in caregiver age was associated with odds of assignment to the Moderate-Decreasing group of 0.98 times the odds of assignment to the Low-Stable group. An association of early motherhood with greater attention problems was reported in the general population study by Vergunst et al. (2019). The association of younger biological parent age with ADHD diagnosis is more well-established, with population-based sibling studies supporting that shared genetic mechanisms largely underlie this association with a smaller role of environmental factors (e.g., mothers engaging in risky behavior during pregnancy) (Chang et al., 2014; Hvolgaard Mikkelsen et al., 2017).

It is possible that the association between younger parental age and ADHD partly underpins previously reported associations of higher socioeconomic risk with ADHD symptoms since parental age is not controlled for in several studies that report a significant association of higher socioeconomic risk with ADHD symptoms (e.g., Choi et al., 2017; Hong et al., 2021; Michaëlsson et al., 2022). In the current study, we did not find an association of socioeconomic risk with caregiver-reported attention problems, including in an exploratory analysis in which age of the primary caregiver was excluded from the model. Several of the previous studies supporting an association of higher socioeconomic risk with ADHD symptoms are larger scale studies in the general population and in autistic individuals (e.g., Choi et al., 2017; Hong et al., 2021; Michaëlsson et al., 2022; Vergunst et al., 2019), such that the absence of a significant association in the current study may relate to insufficient power.

In terms of caregiver depression symptoms, we found that for each one-unit increase on the depression scale of the SCL-90-R, the odds of being in the Moderate-Decreasing group increased by 11%. The magnitude of this association is likely inflated by over-reporting of children's symptoms by depressed caregivers (Bennett et al., 2012; Van der Toorn et al., 2010), however an association between caregiver depression and child ADHD symptoms is expected based on previous literature. Caregiver depression has been prospectively associated with ADHD symptoms in their offspring (Chen et al., 2020). This may partly relate to shared genetic underpinnings of depression and ADHD (Zhao & Nyholt, 2017). It may also relate to parenting practices that have been associated with caregiver depression and that may increase the likelihood or severity of ADHD (Lovejoy et al., 2000; Modesto-

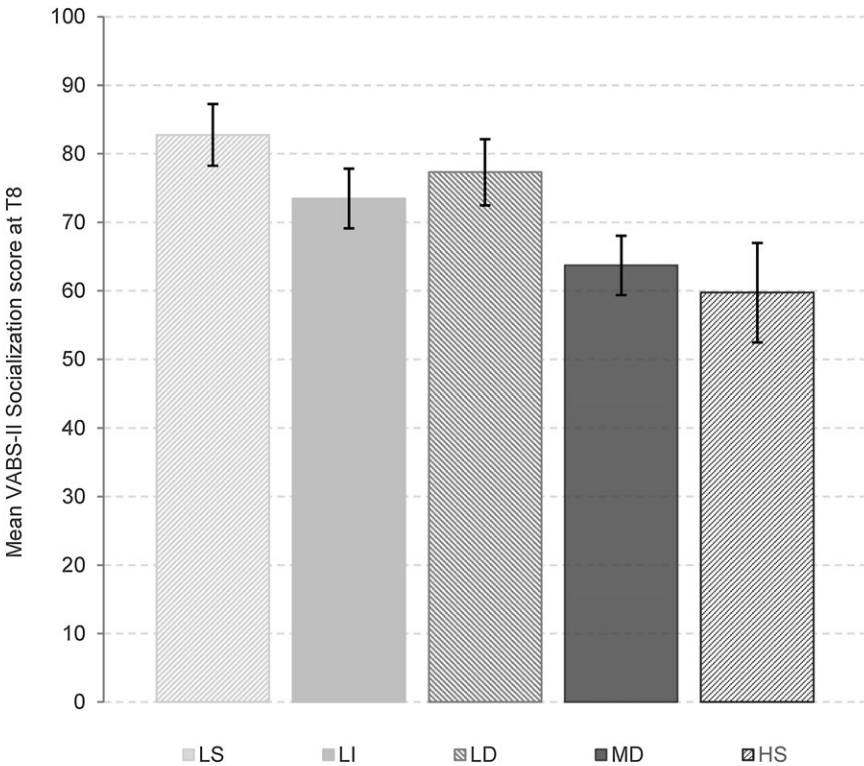

Figure 2. Vineland adaptive behavior scales, second edition (VABS-II) standardized socialization scores in each attention problems trajectory group with 95% confidence intervals. HS = High-Stable; LD = Low-Decreasing; LI = Low-Increasing; LS = Low-Stable; MD = Moderate-Decreasing.

Lowe et al., 2008). Notably, parenting behavior has been found to partly account for the association between caregiver depression during their child's infancy and their child's poorer sustained attention at school entry (Wang & Dix, 2017). Moreover, addressing caregiver mental health alongside provision of behavioral intervention for ADHD has been found to increase caregiver engagement in the intervention and the beneficial effects to the child and family, supporting relevance of caregiver depression to the outcomes of children with ADHD (Chronis-Tuscano et al., 2013; Smith et al., 2015).

We did not find a significant association of child autism symptom severity with caregiver-reported attention problems. This is consistent with null findings in some previous studies (Dellapiazza et al., 2021; Hong et al., 2021) or findings of only a weak association between symptoms of ASD and ADHD (Colvert et al., 2022; Wright et al., 2023). Evidence thus converges that the severity of autism symptoms is not an important determinant of ADHD symptom severity among autistic individuals.

As predicted, we found that autistic children with greater caregiver-reported attention problems were more likely to use psychotropic medications. This was most notable in the Low-Stable and Moderate-Decreasing groups. The current data is insufficient to determine why associations were found in these two trajectory groups only. It is important to bear in mind that psychotropic medications were not only, and perhaps not principally, prescribed for attention problems, such that it is not surprising that we only found limited associations. When specifically examining associations with ADHD medications, we found that autistic children with greater caregiver-reported attention problems were more likely to use ADHD medications, but unlike for psychotropic medications, there was no significant relation of ADHD medications with caregiver-reported attention problems within trajectory groups. Given the low number of children prescribed ADHD medications in most trajectory groups and the small size of the High-Stable trajectory group, null findings are not surprising and should not be interpreted as an indication that ADHD medication is unwarranted or ineffective in autistic children. Indeed, it has been demonstrated that ADHD treatment can be effective in children with co-occurring autism and ADHD (Smith et al., 2016). The current data also do not allow for determination of the directionality of associations between attention problems and psychotropic medication use (i.e., greater attention problems preceding prescription of psychotropic medications or vice versa). Nevertheless, the overall rate of psychotropic medication use in this study is worrisome considering concerns about prescription outside evidence-based indications and limited knowledge about long-term consequences of childhood psychotropic medication use (e.g., Harrington, 2008). We did not find an association of trajectory membership or level of caregiver-reported attention problems within trajectories with use of soft psychotropics. This suggests that factors other than attention problems motivate caregivers to give soft psychotropics to their autistic children and that soft psychotropics do not notably affect children's attention skills.

Autistic children in the Moderate-Decreasing and High-Stable trajectory groups showed lower socialization skills at T8 than participants in the other three groups characterized by lower caregiver-reported attention problems. This adds to the growing evidence that ADHD symptoms are associated with poorer social skills for autistic children. Notably, we found that despite a mean moderate/borderline level of caregiver-reported attention problems at baseline, the Moderate-Decreasing group had similarly low VABS-II Socialization scores at T8 as the High-Stable group, which had mean Socialization scores in the clinical range. The mean VABS-II Socialization score of the Low-Increasing trajectory group was somewhat lower than that of the Low-Decreasing group despite their similar baseline level of attention problems (i.e., only the Low-Increasing group had significantly lower mean VABS

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Socialization Score at T8 than the Low-Stable group) and higher than the Moderate-Decreasing group despite their similar level of attention problems at T8. This pattern suggests that social skills outcome is related to the trajectory of caregiver-reported attention problems and not only to attention problems at the time when social skills are assessed.

Strengths and limitations

An important strength of this study is that analyses were conducted in an inception cohort of children diagnosed with ASD as preschoolers across multiple centers. In addition, the longitudinal design offers an important perspective to understanding the evolving presentation of attention problems in autism. The amount of missing data in the current study was favorable compared to other longitudinal studies of children with medical or neurodevelopmental conditions (Duvekot et al., 2017; Johnson et al., 2016; Williams et al., 2013), and we applied modern missing data approaches that have been shown to counter the biasing effects of nonrandom attrition effectively (Little et al., 2014). Importantly, from among analysis variables and variables previously found to be associated with attrition in the Pathways in ASD study, we identified variables associated with missingness in our outcome variable and examined the influence of these variables in the PROC TRAJ dropout model. We also included these variables in the multiple imputation model. Failure to include such variables in analysis models is a commonly omitted component of missing data handling that is important to reduce bias of produced parameter estimates as these variables may aid in estimating missing values (Lang & Little, 2018).

In terms of limitations of the current study, it is important to bear in mind that because our sample constitutes children diagnosed with ASD as toddlers, it does not represent the entire autistic population. Our sample under-represents individuals with more subtle autistic symptoms and autistic girls, as both groups tend to be diagnosed later. In addition, the AP scale of the CBCL has not been validated in autistic individuals, such that scores on this scale may not have the same meaning as in the CBCL normative sample; they may be influenced by or reflect factors such as autism symptoms or level of intellectual ability (Dovgan et al., 2019; Medeiros et al., 2017; Yerys et al., 2017). To date, no validated ADHD symptom questionnaire is available for autistic children. This gap in the existing literature is important to address given the high rate of co-occurrence of ADHD and autism and the consequent importance of understanding the presentation of ADHD symptoms in autism. Nonetheless, the current study findings bear clinical relevance by supporting that autistic children with higher rates of caregiver-reported attention problems have poorer social skills outcomes at a group level, even if the underlying mechanisms of those reported problems remain to be fully elucidated. Moreover, there were few participants in the High-Stable group such that the absence of significant associations between baseline variables and membership in this group as well as the lack of significant associations between use of psychotropic medication or soft psychotropics and attention problems in this group must be interpreted with caution. Furthermore, we only examined caregiver-reported attention problems, when it is known that attention problems may vary across settings, such that evaluating attention problems across settings is necessary to better understand the extent of these challenges (Wolraich et al., 2019). In addition, since we used caregiver reports for attention problems and social skills, common method variance may have increased associations between higher attention problems and lower social skills. We conducted an exploratory analysis comparing trajectory groups on teacher-reported VABS-II Socialization scores and found similar results (Figure A2 of Appendix), suggesting that the results are not entirely due to caregiver reporting.

In our study of children diagnosed with ASD between the ages of 2–4 years, 11 months, we found that most children had decreasing levels of attention problems, as reported by their primary caregivers from the time of ASD diagnosis until late childhood. In the context of previous multiple trajectory studies of attention problems in younger and older autistic individuals, our findings suggest that decreasing caregiver-reported attention problems from toddlerhood to young adulthood is a common trajectory in autism. Nevertheless, an important minority of autistic children in our sample had high and stable attention problems (7.2%) or increasing attention problems (19.2%). Consistent with previous studies, we found that lower child FSIQ as well as younger primary caregiver age and higher levels of caregiver depression at baseline were significantly associated with greater caregiver-reported attention problems. The latter suggests that interventions that lessen caregiver depression may help to decrease attention problems in autistic children. In addition, we found that attention problems, even those below the clinical threshold, were related to poorer social skills outcomes and that initially low but increasing attention problems over time were related to poorer social skills than low-stable or low-decreasing trajectories. This supports the importance of monitoring attention problems in autistic children and raises the possibility that identifying attention problems early, even if below the clinical threshold, and implementing strategies to improve attentional skills may help to lessen social difficulties of autistic individuals.

Supplementary material. The supplementary material for this article can be found at https://doi.org/10.1017/S0954579425000021.

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Competing interests. The author(s) declare none.

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