NEW RESEARCH

Relative Age Effects on Attention-Deficit/Hyperactivity Disorder Symptoms and Educational Achievement: A Longitudinal UK Cohort Study

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Objective: Being among the youngest in a school class increases the risk for worse educational outcomes and attention-deficit/hyperactivity disorder (ADHD) symptoms, but questions remain about the nature and persistence of such effects. We investigated this "relative age effect" on educational achievement at age 15 to 16 years and on ADHD symptoms from age 7 to age 21 years. Furthermore, we examined whether being young-in-class is linked to a greater reduction in ADHD symptoms from childhood to adulthood and a lower genetic propensity to ADHD.

Method: We identified 3,928 young-in-class and 4,580 old-in-class participants from the Twins' Early Development Study. Educational achievement was measured with mathematics and English examination grades at age 15 to 16 years, and ADHD symptoms were measured using 2 different scales and different raters, from age 7 to 21 years, with effects tested using regression.

Results: A relative age effect emerged for English but not mathematics examination grades, and for the majority of parent and teacher ratings on ADHD symptoms, most consistently in middle childhood. Being young-in-class was associated with a greater reduction in parent-rated ADHD symptoms from childhood to adulthood when measured with a brief scale, but the comparable result from a longer scale was non-significant (after multiple testing correction). No interaction emerged between relative age and ADHD polygenic scores.

Conclusion: Our results emphasise the need to improve support for the children who start school younger than most, and to ensure that developmental comparisons take children's precise age into account. Future research would benefit from in-depth analyses of individual trajectories and their variability among the young-in-class children.

Plain language summary: Young-in-class children are at increased risk for worse educational outcomes and attention-deficit/hyperactivity disorder (ADHD) symptoms, but their persistence is unclear. This study examined data from a large longitudinal UK community sample (3,928 young-in-class and 4,580 old-in-class) to identify age effects on educational achievements and ADHD symptoms. Results showed that young-in-class children are more likely to be rated with ADHD symptoms by both parents and teachers, especially in middle childhood, and have lower English exam grades at age 15 to 16.These results emphasize the need to improve support for children who start school younger than most and ensure that developmental comparisons take children's precise age into account.

Key words: polygenic score; attention-deficit/hyperactivity disorder; relative age; Twins Early Development Study (TEDS)

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An increasing number of large-scale studies show that children who are younger than most of their peers in the same class are at a disadvantage in relation to a range of outcomes, including educational and sports achievement, substance use disorder, specific learning disorders, and language skills.[1-4] This phenomenon is known as the relative age effect. The relative age effect on educational achievement has been observed for a wide range of measures and ages.[5] In the United Kingdom, pupils take national examinations, General Certificate of Secondary Education (GCSE), at age 15 to 16 years. Using data from the Millennium Cohort Study and the Longitudinal Study of Young People in England, Bernardi and Grätz[6] reported relative age effects for both English and Mathematics GSCE results: children born in August (the youngest in class) were 6.6% less likely to receive at least 5 GCSEs with grades between A* and C, compared to children born in September (the oldest in class).

A large evidence base shows that the relative age effect emerges also for the diagnosis of attention-deficit/hyperactivity disorder (ADHD). Two partially overlapping meta-analyses on large cohort and register studies,[7,8] across many countries and continents, reported a significant relative risk of around 1.3 in comparisons between the oldest and youngest children within the school year on ADHD diagnosis or treatment. The relative age effect cannot be explained by the season of birth, as the effects emerge across different countries and school systems with different school starting months.[7,8]

It is also informative to consider what may explain the lack of a relative age effect on ADHD in a small number of studies. In register-based data emerging from the 5 Nordic countries, the Danish dataset was exceptional in not reporting a clear relative age effect for ADHD.[8] Denmark follows a more flexible approach to school starting age, with a high proportion of relatively young children held back by 1 year, which has been suggested to account for the lack of relative age effect in their dataset.[9] Similar findings emerged from a recent comparison between data from Wales and Scotland: diagnosis of ADHD was more common among the young-in-class in Wales than in Scotland, where holding back relatively young children is common.[10]

A number of population-based studies have also reported a relative age effect on ADHD symptoms.[7,11-15] Most studies reported such effects for both parent and teacher ratings on ADHD symptoms,[7,13-15] but in a Swedish study no significant effect emerged for parent ratings.[16] Diefenbach *et al.*[13] further reported that the relative age effects appeared in parent ratings only at the end of the first grade and not prior to school entry or 3 months thereafter. Similarly, Broughton *et al.*[12] found no relative age effect prior to school entry. The only study, to our knowledge, to examine the relative age effect on self-ratings of ADHD symptoms found no such effect in a population sample of adults.[16]

ADHD is highly heritable (74%),[17] and, in 2019, a genome-wide association study (GWAS) first identified 12 common genetic variants that are significantly associated with the disorder.[18] In an updated GWAS on ADHD, published in 2023, the number of genome-wide significant loci increased to 27.[19] GWASs enable further genetic investigations using polygenic score (PGS), which are calculated for each individual by computing the sum of their risk alleles across the genome, weighted by effect sizes.[20] A PGS provides an estimate of the genetic propensity to ADHD at the individual level that can be used to investigate shared genetic etiology between ADHD and other phenotypes.[21] The ADHD GWAS further provided strong evidence that clinical diagnosis of ADHD represents the extreme of a continuous heritable trait.[18]

The observations that ADHD reflects the extreme of a continuous trait, and that ADHD diagnosis specifically relies on a relative comparison to other children of the same age, led to a possible explanation for the relative age effect: a child with moderate ADHD symptoms but who is young-in-class could more easily appear to cross the threshold to diagnosis if inaccurately compared to relatively older peers. If so, some young-in-class children with ADHD may have less severe ADHD or a lower genetic loading for ADHD if they have crossed the threshold to diagnosis partly due to their relative immaturity. ADHD symptoms, specifically hyperactive-impulsive symptoms, in general decrease with age.[22] As relative immaturity may have less of an impact as the child gets older, this leads to the prediction of a greater reduction in ADHD symptoms from childhood to adulthood in those who were young-in-class (ie, assuming that their initial symptoms were inflated), compared to their older peers.

We now test the following hypotheses using the Twins' Early Development Study (TEDS)[23-26] population sample that has followed twins born in England and Wales between 1994 and 1996 to adulthood.

First, we will first investigate the following: (1) whether the relative age effect emerges for educational achievement as measured with GCSE grades for English and mathematics; and (2) whether the relative age effect emerges for ADHD symptoms in this general population sample, at ages from 7 to 21 years (parent ratings at ages 7, 8, 9, 12, 14, 16, and 21 years; teacher ratings at ages 7, 9, and 12 years; and self-ratings at ages 12, 14, and 21 years). Although the analyses on GCSE data reflect, in part, a replication of data from Bernardi and Grätz,[6] we focus on actual GCSE scores for each subject (range 1-9, covering outcomes from fail to A*), rather than using the dichotomous classification based on "at least 5 GCSEs with grades between A* and C."[6] Using the full range of actual GCSE scores enables a sensitive analysis of educational achievement as a continuous dimension. For the analyses on ADHD symptoms, the TEDS dataset enables us to assess the relative age effect for different raters (parents, teachers, self) across multiple time points from childhood to adolescence and, for parent and self-ratings, to adulthood. Second, we will test whether a greater reduction in ADHD symptoms from childhood to adulthood is observed for the young-in-class group compared to their older peers. Third, we will test whether ADHD PGS is less strongly associated with ADHD symptoms among the young-in-class group compared to their older peers.

METHOD

Participants

Participants were drawn from the TEDS, a United Kingdom representative sample of twins born in England and Wales between 1994 and 1996.[23-26] Participants with pre- or perinatal complications, severe congenital anomalies, severe autism spectrum disorder (non-verbal or with severely delayed speech, or with difficulties in completing activities), chromosomal disorders, and those who failed to provide zygosity information were excluded.

A total of 13,017 pairs of twins were included in the current analysis. Schools in England and Wales run from each September until August of the following year. All TEDS participants were born between January 1, 1994, and December 31, 1996, and therefore fall into 4 school year or cohort groups (Table S1, available online). To gather representative data for whole academic years and to prevent data biases, we included only cohort 2 and cohort 3 of the 4 cohorts. Participants who were born in June to August (young-in-class), as well as those born in September to November (old-in-class) were included, resulting in a final study sample of 8,508 participants. A longitudinal data structure was used with all related participants, and available data were collected from ages 7 to 21 years. A comparison between the final study sample and the initial sample is presented in Table S2, available online; there were no differences in zygosity or gender. Ethical approval for TEDS has been provided by the King's College London ethics committee. Written informed consent was acquired from parents prior to data collection. All human studies have been approved by the appropriate ethics committee and have been conducted under the Declaration of Helsinki (1964) and its later amendments.

Measures

ADHD symptoms were assessed with the *Diagnostic and Statistical Manual of Mental Disorders* (*DSM-IV*)–based Revised Conners' ADHD symptoms Parent Rating Subscale and Self-Report Rating Subscale (Conners' ADHD symptoms subscale)[27] at age 8 (parent-rated), 12 (parent-rated), 14 (parent- and self-rated), 16 (parent-rated), and 21 (parent-rated) years, and the Strengths and Difficulties Questionnaire (SDQ) hyperactivity/ inattention scale[28] at age 7 (parent-, teacher- and self-rated), 9 (parent- and teacher-rated), 12 (parent-, teacher- and self-rated), 16 (parent- and self-rated), and 21 (parent- and self-rated) years. All available scales were included in analyses for the first study aim, whereas only parent-rated scales were included in the second and third aims, given that only data from parent-rated scales are available in both childhood and adulthood.

Conners' Scale. The 18 items of the Revised Conners' ADHD symptoms Parent Rating Subscale and Self-Report Rating Subscale are rated on a 4-point Likert-type scale reflecting the frequency of each item: with 0 as "not at all" to 3 as "very much true." Higher score indicates greater severity. The Revised Conners' Parent Rating Subscale and Self-Report Rating Subscale assesses ADHD symptoms based on 18 items, 9 of which assess hyperactivity-impulsivity and 9 assess inattentiveness. The standardized Cronbach alpha across the 5 ages was 0.84.

SDQ Hyperactivity/Inattention scale. This 5-item scale is part of a 25-item SDQ questionnaire designed to measure common mental health problems during childhood and adolescence. Items of the SDQ are rated on a 3-point Likert-type scale reflecting the frequency of each item, with 0 as "not true" to 2 as "certainly true." Higher scores indicate greater severity. The standardized Cronbach alpha across the 5 ages was 0.85.

Educational achievement was assessed using English and mathematics scores from the GCSE examinations at age 15 to 16 years. The GCSE is a standardized UK-based examination administered at the end of compulsory education at age 15 to 16 years. Almost all students take the 3 core subjects: English, mathematics, and science. In addition, students are allowed to choose a range of other subjects. The subjects are graded from 4 (G, the minimum pass grade) to 11 (A*, the best possible grade). Receiving 5 or more at grades A* to C is typically a requirement for going on to further education. Data collection was done by telephone interviews and mail questionnaires to the twins and their parents. The grades were verified using the National Pupil Database (NPD), yielding a correlation of 0.99 for mathematics and 0.98 for English.[25]

The PGS for ADHD was derived from a genome-wide association study.[18] Analyses included genomic principal components and genotyping batch as covariates.[29] Interaction terms between covariates and variables of interest were also included in the interaction model. Details are provided in Supplement 1, available online.

Statistical Analyses

Analyses were pre-specified and registered on Open Science Framework (https://osf.io/hv5gj). Minor deviations from these pre-specified analyses are explained in Supplement 1. Analyses were performed with Stata Software Version 16.1. Analyses were undertaken with all the available data. The available case analysis was used, for each analysis; participants with missing data on the variables used for analyses were excluded, resulting in a varied number of observations across analyses. The standardized values of questionnaire completion age (in decimal year) were included as a covariate in analyses of all aims. Also, PGS in aim 3 was analyzed along a set of covariates. The detailed construction of these covariates is provided in Supplement 1, available online. Linear regressions with robust standard errors (-cluster- option) were used to account for the

TABLE 1 Descriptive Statistics of Young-in-Class Group vs Old-in-Class Group

			Relative age	
			Young-in-class	**Old-in-class**
Participant characteristics				
Observation, n (%)			3,928 (54)	4,580 (46)
Male gender, n (%)			1,924 (49)	2,372 (52)
GCSE score, mean (SD)				
Mathematics			8.92 (1.42)	8.92 (1.43)
English			8.86 (1.20)	8.97 (1.20)
ADHD symptoms, mean (SD)	**Age**	**Rater**		
Conners'	8	Parent	12.11 (10.09)	10.1 (8.48)
	12	Parent	10.88 (9.47)	8.75 (7.74)
	14	Parent	9.53 (8.81)	7.66 (7.66)
		Self	13.99 (8.44)	13.16 (7.84)
	16	Parent	7.31 (7.82)	6.22 (6.96)
	21	Parent	7.12 (7.92)	5.73 (6.40)
SDQ	7	Parent	3.82 (2.56)	3.39 (2.49)
		Teacher	3.30 (2.76)	2.68 (2.65)
	9	Parent	3.40 (2.43)	3.96 (2.35)
		Teacher	2.86 (2.56)	2.26 (2.34)
	12	Parent	3.04 (2.37)	2.60 (2.14)
		Teacher	2.21 (2.53)	2.01 (2.36)
		Self	3.67 (2.27)	3.33 (2.27)
	16	Parent	2.32 (2.03)	2.20 (1.94)
		Self	3.71 (2.31)	3.60 (2.29)
	21	Parent	2.04 (2.06)	1.87 (1.94)
		Self	3.44 (2.21)	3.23 (2.22)

Note: Conners' = Revised Conners' ADHD symptoms Parent Rating Subscale and Self-Report Rating Subscale; GCSE = General Certificate of Secondary Education; SDQ = Strengths and Difficulties Questionnaire.

nonindependence within twin pairs in the sample and to provide valid inference on the non-normality of residuals.[30] Results are presented with 95% confidence intervals.

We used an adjusted alpha of 0.003 for aim 1 and 0.025 for aim 2 and aim 3 by performing multiple testing corrections. Principal component analyses on the correlation matrix of independent variables were carried out to evaluate the number of independent tests. Numbers of principal components that account for 99.5% of the variance from the principal component analysis were used to perform Bonferroni corrections.

RESULTS

Descriptive statistics for participant characteristics and measures are displayed separately for the young-in-class group and old-in-class groups in Table 1. A χ^2 test was performed on gender between 2 groups, which showed that relative age and gender were non-independent of each other (Pearson $\chi^2[1] = 6.67$; $p = .010$), with more male participants in the old-in-class group. Full results including covariates for all aims and the results of sensitivity analysis are included in Table S3 to Table S6, available online).

Relative Age Effect on ADHD Symptoms and Educational Achievement

Parent-rated Conners' ADHD symptoms were all positively associated with young relative age (Table 2; full statistics including covariates are presented in Table S7, available online). For example, the ADHD symptoms scores of the parent-rated Conners' subscale at age 8 years were about 2.01 points higher for the young-in-class group than for the old-in-class group. The self-rated Conners' ADHD symptoms at age 14 years were not significantly associated with young relative age.

Parent-rated SDQ hyperactivity/inattention symptoms were significantly positively associated with young relative age at age 7 and age 12 years, but not at age 9, age 16, and age 21 (p values at ages 9 and 21 were .008 and .025, respectively, but non-significant following multiple testing correction) (Table 2). Teacher-rated SDQ hyperactivity/inattention symptoms were positively associated with young relative age at age 7 and at age 9, but not at age 12. Self-rated SDQ hyperactivity/inattention symptoms were positively associated with young relative age only at age 12 but not at ages 16 or 21 (p value at age 21 was 0.023, which was non-significant following multiple testing correction).

Young relative age was significantly negatively associated with English GCSE scores but not with mathematics GCSE scores (Table 2).

Attenuation of the Relative Age Effect on ADHD Symptoms Across Age

The regression models revealed a significant effect of relative age on the attenuation of ADHD symptoms on the parent-rated SDQ hyperactivity/inattention scale from age 7 to age 21 (Table 3). Being young-in-class resulted in an additional 0.37 symptom score decrease from childhood to adulthood, compared to old-in-class group. The same analysis on the parent-rated Conners' ADHD symptoms subscale from age 8 to age 21 produced a p value of .043 for the interaction effect, which failed to pass the adjusted alpha of 0.025.

Interaction Between Relative Age and ADHD PGS

Table 4 shows the results when both ADHD PGS and relative age were included in the regression model. Both

TABLE 2 Regression Models of Attention-Deficit/Hyperactivity Disorder (ADHD) Symptoms for Relative Age

			Relative age			
ADHD symptoms	**Age, y**	**Rater**	**Coefficient**	**[95% CI]**	***p***	**n**
Conners'	8	Parent	**2.01**	[1.30 to 2.71]	<0.001	4,162
	12	Parent	**2.23**	[1.53 to 2.93]	<0.001	3,642
	14	Parent	**1.94**	[0.99 to 2.88]	<0.001	1,850
		Self	0.76	[−0.09 to 1.61]	0.078	1,831
	16	Parent	**1.13**	[0.50 to 1.77]	<0.001	3,141
	21	Parent	**1.40**	[0.81 to 1.99]	<0.001	3,422
SDQ	7	Parent	**0.42**	[0.25 to 0.58]	<0.001	4,685
		Teacher	**0.66**	[0.45 to 0.86]	<0.001	3,751
	9	Parent	0.34	[0.09 to 0.59]	0.008	1,930
		Teacher	**0.60**	[0.33 to 0.87]	<0.001	1,697
	12	Parent	**0.46**	[0.29 to 0.63]	<0.001	3,638
		Teacher	0.19	[−0.01 to 0.40]	0.063	3,081
		Self	**0.33**	[0.16 to 0.50]	<0.001	3,626
	16	Parent	0.13	[−0.03 to 0.29]	0.125	3,135
		Self	0.11	[−0.07 to 0.29]	0.217	3,129
	21	Parent	0.18	[0.02 to 0.33]	0.025	3,413
		Self	0.20	[0.03 to 0.38]	0.023	3,009
GCSE score, mean [SD]						
English			**−0.11**	[−0.21 to −0.02]	0.020	4,039
Mathematics			−0.01	[−0.12 to 0.10]	0.830	4,020

Note: Conners' = Revised Conners' ADHD symptoms Parent Rating Subscale and Self-Report Rating Subscale; GCSE = General Certificate of Secondary Education; n = number of observations; SDQ = Strengths and Difficulties Questionnaire.

parent-rated Conners' ADHD symptoms and SDQ hyperactivity/inattention symptoms were significantly associated with relative age and ADHD PGS.

As both relative age and PGS were associated with ADHD symptoms (main effects; Table 4), we added an interaction term of relative age and ADHD PGS (ie, relative age * ADHD PGS; Table 5). In the interaction model, parent-rated Conners' ADHD symptoms were significantly associated with relative age and ADHD PGS, but not with the interaction. Parent-rated SDQ hyperactivity/inattention symptoms were significantly associated with relative age, but not with ADHD PGS ($p = .04$; non-significant following multiple testing correction) and the interaction.

TABLE 3 Regression Models of Attenuation of Attention-Deficit/Hyperactivity Disorder (ADHD) Symptoms for Relative Age

	Relative age			
ADHD symptoms	**Coefficient**	**[95% CI]**	***p***	**n**
Attenuation from age 7 y to age 21: Parent-reported SDQ	**0.37**	[0.15-0.58]	0.001	2,766
Attenuation from age 8 y to age 21: Parent-reported Conners'	0.82	[0.03-1.62]	0.043	2,615

Note: Conners' = Revised Conners' ADHD symptoms Parent Rating Subscale and Self-Report Rating Subscale; n = number of observations; SDQ = Strengths and Difficulties Questionnaire.

DISCUSSION

Using a large longitudinal community sample, the present study identified significant relative age effects on GCSE examination results for English and for the majority of parent and teacher ratings on ADHD symptoms. The overall pattern of results indicates a reduction in the relative age effect from childhood to adulthood for ADHD symptoms when measured using parent ratings on the brief SDQ scale, but a more persistent pattern of relative age effects when measured using parent ratings on the detailed Conners ADHD symptoms subscale. Our analyses did not support the hypothesis that ADHD PGS would be less strongly associated with ADHD symptoms among the young-in-class compared to their older peers.

We extend previous research on relative age effects on educational outcomes[5] by showing that such an effect

TABLE 4 Regression Models of Attention-Deficit/Hyperactivity Disorder (ADHD) Symptoms for Relative Age and Polygenic Score (PGS)

			Relative age			PGS			
ADHD symptoms	**Age**	**Rater**	**Coefficient**	**[95% CI]**	***p***	**Coefficient**	**[95% CI]**	***p***	**n**
Conners'	8	Parent	**1.84**	[1.03-2.66]	<.001	**1.36**	[0.95-1.78]	<.001	2,388
SDQ	7	Parent	**0.38**	[0.18-0.58]	<.001	**0.35**	[0.25-0.45]	<.001	2,628

Note: Conners' = Revised Conners' ADHD symptoms Parent Rating Subscale and Self-Report Rating Subscale; n = number of observations; PGS = polygenic score; SDQ = Strengths and Difficulties Questionnaire.

emerged for GSCE examination results at ages 15 to 16 for English but not for mathematics. Bernardi and Grätz[6] observed relative age effects for both mathematics and English when analyzing the data using a categorical approach based on a cut-off of 5 GCSE with grades A* to C. Our results suggest that when focusing on the full continuum of scores, which enables a more sensitive analysis of differences also between average and top scores, only performance on the English examination was related to the pupils' relative age. The long-lasting disadvantage for children who enter the school system younger than most of their peers, in relation to their future achievement in the core subject of English, is particularly concerning and calls for a detailed educational consideration of potential intervention approaches.

Although we observed wide-ranging relative age effects on ADHD symptoms, our detailed analyses show that the results depend on age, rating scale, and rater. When using the 18-item parent-rated Conners' ADHD symptoms subscale, we observed a consistent pattern of significant relative age effects across development (ie, at ages at ages 8, 12, 14, 16, and 21 years), extending previous findings.[7,13,14] However, no relative age effect emerged for self-rated Conners' ADHD symptoms at age 14, similar to the previous report by Halldner *et al.*[16] using a comparable scale with adults. In contrast to our findings, Halldner *et al.*[16] did not observe a relative age effect for parent-ratings on ADHD symptoms on a comparable scale at age 9, but the differences in results could be due to us adopting a fully dimensional approach whereas Halldner *et al.*[16] used sliding cut-offs.

The brief 5-item SDQ scale produced significant relative age effects on ADHD symptoms at the younger ages only: at ages 7 and 12 for parent ratings, at ages 7 and 9 for teacher ratings, and at age 12 for self-ratings. However, this pattern was not strictly chronological. The relative age effects were not significant for SDQ ADHD symptoms at ages 9, 16, and 21 for parent ratings, at age 12 for teacher ratings, and at ages 16 and 21 for self-ratings. This pattern is largely in agreement with previous studies.[7,12,13] Overall, the evidence suggests that the brief SDQ scale may pick up relative age effects on ADHD symptoms at the ages when the effects emerge as the strongest also for ADHD diagnosis,[16] whereas the longer Conners' ADHD symptoms subscale picks up significant differences throughout, from childhood to adulthood, at least when using parent ratings (teacher ratings on this subscale were not available).

Our longitudinal analyses further confirmed the differences observed between the data from the brief SDQ scale vs Conners' ADHD symptoms subscale: being young-in-class resulted in a greater attenuation in parent-rated SDQ ADHD symptoms from childhood to adulthood in these individuals compared to their older peers, whereas the effect was not significant (following multiple testing correction) for parent-rated Conners' ADHD symptoms. The longitudinal result from the SDQ is in line with the possibility that parent-rated ADHD symptoms are inflated for the young-in-class children due to an inappropriate comparison to older peers, with such relative immaturity effect reducing with age. Yet the signal for such an effect was

TABLE 5 Regression Models of Attention-Deficit/Hyperactivity Disorder (ADHD) Symptoms for Relative Age, Polygenic Score (PGS), and Their Interaction

			Relative age			PGS			Interaction			
ADHD symptoms	**Age**	**Rater**	**Coefficient**	**[95% CI]**	***p***	**Coefficient**	**[95% CI]**	***p***	**Coefficient**	**[95% CI]**	***p***	**n**
Conners'	8	Parent	**2.21**	[1.07-3.34]	<.001	**0.98**	[0.27-1.69]	<.001	−0.12	[−0.95 to 0.70]	.767	2,388
SDQ	7	Parent	**0.42**	[0.57-0.78]	.023	0.21	[0.01-0.41]	.040	−0.04	[−0.25 to 0.18]	.726	2,628

Note: Conners' = Revised Conners' ADHD symptoms Parent Rating Subscale and Self-Report Rating Subscale; n = number of observations; PGS = polygenic score; SDQ = Strengths and Difficulties Questionnaire.

weak for the Conners' data and did not survive correction for multiple testing, calling for a more in-depth consideration of differences between the SDQ and Conners' data. The higher p value for the Conners' data ($p = .04$, compared to $p = .001$ for the SDQ data) relate to the very high 95% confidence intervals observed for this subscale (0.03-1.62, compared to 0.15-0.58 for the SDQ data), which indicate high within-group variability in the attenuation of ADHD symptoms over time. These observations show that when ADHD symptoms are captured using parent ratings on the more detailed Conners' ADHD symptoms subscale, the extent of attenuation of symptoms from childhood to adulthood varies greatly within group. A more in-depth investigation of individual trajectories for young-in-class children is an important direction for future research. In addition to the difference between the 2 scales, another difference between our 2 sets of longitudinal analyses is that the baseline ADHD symptoms data were obtained at age 7 from the SDQ but at age 8 from the Conners' ADHD symptoms subscale. The longer interval for the analyses on the SDQ data may have contributed to the significant interaction effect of relative age and attenuation of ADHD symptoms over time.

We did not obtain support for the hypothesis that ADHD PGS would be less strongly associated with ADHD symptoms among the young-in-class compared to their older peers, as the PGS-by–relative age interaction was not significant. Further research is needed to establish whether this reflects a true null finding or limited power in our study to pick up a significant effect. This non-significant interaction may be due to the following. (1)The PGS that we used was based on the 2019 ADHD GWAS, with 12 significant loci, capturing only part of the overall genetic influences on ADHD.[18] The new 2023 ADHD GWAS on an updated, larger sample size identified an increased number of 27 loci associated with ADHD[19] and may lead to improved PGS analyses in the future. (2) In addition, we note that the GWAS from which we constructed the ADHD PGS will likely already be enriched for young-in-class children with ADHD, because ADHD is overdiagnosed in this group. This could result in a correlation between the PGS and relative age that may attenuate the PGS-by–relative age interaction. ADHD PGS was positively associated with ADHD symptoms as a main effect, highlighting the partly genetic nature of ADHD.[19] Young relative age was associated with increased ADHD symptoms, independent of the ADHD PGS.

The present study has certain limitations. First, even in a population sample, individuals with the most severe ADHD symptoms may be taking ADHD medication, which could ease the symptoms. We did not have access to information about ADHD medication and therefore were not able to incorporate medication use as a covariate in the analysis. Second, as the available case analysis was used, the varying number of observations across analyses may have some effect on the comparability between analyses. Third, unlike most studies that have used parent-rated ADHD symptoms, our sample is a twin cohort. Parents were therefore not only comparing their children to the children's peers, but may also have compared behavior between their twin children (with identical ages). Because we still observed significant relative age effects for most parent ratings, this suggests that parents of twins do, however, compare their behavior to that of their children's peers to a significant degree. Future studies could investigate whether the relative age effect varies depending on whether the twins went to the same school.

Overall, the evidence for disadvantages relating to starting school among the youngest-in- class is widespread. Here we report such relative age effects on the objective educational achievement outcome of GCSE English results and on ratings by parents and teachers on ADHD symptoms, most consistently in middle childhood. Questions remain about the underlying mechanisms and what may lead to developmentally persisting negative effects for some, but not all, outcomes; future research has the challenge of developing advanced methodologies for further unpacking the effects and potential interactions over time. For example, is the relative age effect on English examination performance at age 15 to 16 due to cumulative effects on learning (ie, falling behind due to initial difficulties resulting from relative immaturity), or are such effects largely mediated by early negative effects on self-esteem (the early labeling of a relatively young child as having low ability in the subject)?

Children's future chances, or whether their behavior is judged as developmentally inappropriate, should not relate to their month of birth. Potential interventions to reduce relative age effects include a more flexible approach to school starting age,[8,31] as is already applied in some countries such as Denmark[9]; raising awareness of who is relatively young within the classroom, for example by organizing school register by age within school year[12]; and schools monitoring the month of birth and therefore relative age of children who are referred for an ADHD assessment, to help avoid potential referral bias relating to relative age (see also Kuntsi[31]). Our data on parent ratings suggest that it will be important to include parents, too, in the efforts to raise awareness of how to support the children who start school younger than most and to ensure that developmental comparisons take their younger age into account. Equally, we should also ensure that children who are oldest in the class are not less likely, for example, to be referred to specialist assessments where required.[31]

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