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ADHD and secondary school grades: evidence from two longitudinal studies

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Abstract

Academic underperformance is a common problem of pupils with attention-deficit hyperactivity disorder (ADHD). The current study investigates two longitudinal cohorts of pupils over three years, beginning when they were on average 12 years of age. Cohort 1 consisted of pupils with ADHD and a control group (N=282) that were assessed from 2012 to 2015. Cohort 2 consisted of pupils with ADHD and a control group (N=170) that were assessed from 2019 to 2022. Control groups were matched by age in months, gender, and dyslexia leading to a total sample of N=368. A constant and consistent achievement gap between the two groups could only be found in both mathematics and language grades when ADHD was not comorbid with dyslexia. In the smaller sub-samples of pupils with both ADHD and dyslexia, no significant performance differences could be found due to large differences between individuals. Thus, the co-occurrence of ADHD and dyslexia can obfuscate the academic performance gap that is one of the core problems of ADHD. Moreover, path modeling showed that influence of ADHD on school grades was significant at the beginning but diminished towards the end of secondary education. Extraneous factors such as parent education and migration background as well as pupils' gender were correlated with school grades especially in the more recent cohort 2, most likely because of fewer pupils were on an academic trajectory. A broad educational policy implication is to support pupils from disadvantaged parental backgrounds.

Keywords School grades · ADHD · Longitudinal trajectories · Mathematics · Language · Dyslexia

There is an international consensus that attention-deficit hyperactivity disorder (ADHD) is a clinical problem that has been recognized since 1775 and can have different causes such as genetic and environmental risk factors (Ayano et al., 2023; Faraone et al., 2021). It is more prevalent in boys than in girls (Ayano et al., 2023). Incidence rates vary in different countries, from estimates of 3.4% globally to 16.6% in specific populations (Ayano et al., 2023). Pupils with ADHD in general show reliably lower school grades than control groups (Frazier et al., 2007). Further meta-analytic evidence (Faraone et al., 2021) demonstrated that general intelligence is not a contributing factor, but that individual differences in gratification delay tolerance characterize ADHD. Children and adolescents favor small immediate over large but delayed rewards, resulting in impulsive and risky decision-making and variable reaction times, but both these deficits declined with age. Thus, an optimistic hypothesis would be that school performance may be affected in adolescents with ADHD in secondary school, but this could change over time. The current study investigates potential differences between students with and without ADHD and may shed light on whether and how a performance gap between the two groups closes over time.

A recent meta-analysis showed that teacher knowledge about ADHD and behavior management can be improved by continuing education, but the effect often has dissipated a few months later (Ward et al., 2022). Few studies adopted longitudinal designs to study changes during students' school careers. Moreover, school grades reflect not only assessments of pupils' competencies, but also include teachers' personal evaluations of behavioral aspects such as completion of assignments, participation in classroom discussions, and attention to instructions that all can be influenced by the classroom environment management (Strelow

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et al., 2021). As such, we expected that school grades of adolescents with ADHD would be sensitive to pupils' behavior and could be lower than those of typically developing mainstream children. We compared school grades of two samples of pupils with ADHD and age- and gender-matched comparison groups from two large, nationwide longitudinal studies in Germany. The longitudinal exploration of the educational trajectories of their school performance aims to deliver important results whether and in which way school grades of pupils with ADHD benefit from attending inclusive schooling. Inclusive schooling refers to schools that include pupils with special educational needs and disabilities (SEND). While inclusive education is now a legal requirement in European states, educational systems face several challenges when implementing such changes at the national level as school administrations may be keeping special support schools in place in parallel to inclusive schools (Lang et al., 2011; Lange, 2017).

ADHD and the association with school grades

The diagnosis of ADHD requires that problems should occur at least in two contexts, that is at school and at home (Anastopoulos, & Beal, 2020). In adolescence, behavioral problems can, for instance, include using alcohol and illicit substances, spending time with peers who engage in deviant behaviors, driving accidents, and experiencing conflict with their parents. In the United States, about two-thirds of the population with ADHD is treated with medication, and about half with behavioral intervention (Danielson et al., 2018). The potential variations in learning outcomes of children and teenagers with ADHD have been a concern for many years (e.g. Loe, & Feldman, 2007; Raggi, & Chronis, 2006), and remain so (e.g. Frolli et al., 2023; Varrasi et al., 2023). In this research, academic interventions are one major approach for trying to ameliorate ADHD symptoms in school.

Other than behavioral problems at school, sluggish cognitive tempo in tasks is assumed to be typical for children and adolescents with ADHD (Fredrick et al., 2020). Daydreaming was associated with global impairment, while sleepiness/tiredness was associated with organizational problems, and depression could be confirmed as a significant factor in ADHD (McBurnett et al., 2014). Indeed inattention, but not hyperactivity or executive function is linked to depression already in primary school children (Bernad et al., 2016) and in adolescents (Fenesy, & Lee, 2022). The sluggish tempo is more noted by teachers than by pupils (Holdaway, & Becker, 2018) and is related to low motivation for homework (Smith et al., 2019), a factor that enters into school grades.

Both academic and disciplinary problems in childhood ADHD predicted job loss in adulthood (Kuriyan et al., 2013). Thus, ADHD symptoms have recently been summarized in the diagnosis of a cognitive disengagement syndrome (CDS) which can be observed in adolescents with or without an established diagnosis of ADHD (Becker et al., 2023). Becker and colleagues (2023) also found that CDS symptoms were related to poorer homework performance, lower math fluency, lower daily academic motivation and, not surprisingly, also lower school grades. Moreover, conduct disorder (CD) and ADHD are correlated, but only ADHD is correlated with low motivation (Palmu et al., 2023). This makes sense given that inattention appears to be the most relevant constraint in ADHD resulting in negative learning experiences (Palmu et al., 2023). Of three areas, behavior regulation, emotion regulation and cognitive regulation, the teachers, parents and the adolescents themselves agreed that cognitive regulation was the most important factor for progressing in school (Shroff et al., 2023). Another important finding was that ADHD and executive function (EF), consisting of inhibition (self-monitoring), working memory and planning, were highly correlated ($0.43 < r < .77$) on three consecutive measurement occasions when adolescents were 13 to 16 years old. Interestingly, general intelligence was not significantly correlated with EF in pupils with ADHD, with zero to low correlations, $0.00 < r < .16$ (Shroff et al., 2023, see their Table 2). Instead, their parents' income, ADHD scores and EF deficits were continuously significantly correlated with adolescents' executive functioning. Also other studies showed that there is a strong recurrence of ADHD between parents and offspring (e.g. Solberg et al., 2021).

Adolescents with ADHD also have significantly lower grade point averages, more absences, more placements in remedial courses, receive more failing grades, and are more likely to drop out of school (Evans et al., 2020; Kent et al., 2011). Training interventions of pupils with ADHD in inclusive U. S. secondary schools to increase organization skills and homework performance improved ratings by parents, but not self-ratings and those of teachers (DuPaul et al., 2021; Green et al., 2020). In undergraduates with ADHD, test anxiety, math anxiety and literacy anxiety were measured in addition to their actual performance (Di Lonardo Burr, & LeFevre, 2021). It turned out that ADHD symptoms were not directly related to math or literacy performance, but the feelings of students with math or literacy anxiety were justified as their performance was indeed lower. Moreover, a large longitudinal Finnish study with 9,432 participants over a period from age 7 to age 16 showed that the 530 adolescents with ADHD in mainstream education had lower marks in their overall average school grade as well as in mathematics and in their national language Finnish, repeated a school year more often, and their aspirations were less ambitious (Taanila et al., 2014). A surprising result of this study was that the 1,198 pupils with specific learning difficulties showed these issues only if they had a diagnosis of ADHD in addition, that is, ADHD was more predictive for this array of school problems than learning difficulties. Thus, ADHD as a developmental disorder deserves more in-depth research as on the one hand, ADHD is often a condition that is comorbid with other developmental problems, on the other hand, ADHD is marked by problems that are very specific.

ADHD schooling in the United States and Germany

ADHD is a neurodevelopmental disorder (American Psychiatric Association, 2013, DSM diagnostic code 314.01; World Health Organization (WHO), 2025, ICD diagnostic code 6A05) and individuals with ADHD vary broadly in regard to their levels of functioning. In the United States, about half of children and adolescents with ADHD are in special education, usually because of another diagnosis such as emotional behavioral disorder (EBD), learning disability (LD) or other health impairment (OHI) because ADHD is not one of the disability categories (Rhinehart et al., 2022). Alternatively, children and adolescents with ADHD may receive school-based support according to the U. S. Rehabilitation report of 1973 that ensures that they can participate in mainstream education via '504 plans'. Inclusion in mainstream schools is often simply achieved by a reduction of expectations, but the 504 plans also specify how academic deficits could be addressed although they rarely prescribe behavior management strategies for teachers (Hustus et al., 2020; Spiel et al., 2014).

Like in the United States, also in Germany ADHD does not count as special needs or SEND (special educational needs and disabilities), but instead ADHD is classified as '*Teilleistungsschwäche*' [partial performance weakness] which amounts to a diagnosis of a selective deficit in the academic domain, along with dyslexia and dyscalculia. In contrast, SEND encompasses learning difficulties, mental retardation, sensory deprivation, autism, as well as emotional, social and language difficulties that are not further specified. Thus, like in the United States, also in Germany pupils with ADHD could always participate in mainstream schooling unless they had additional problems that required support in special schools.

In a study of inclusive secondary school, pupils with ADHD from nine U. S. urban, suburban, and rural locations who were on special teaching plans (504 plans), the school subject mathematics was top of the problem list with two-thirds (66.7%) of the pupils with ADHD struggling, while about half of them experienced difficulties in reading comprehension (50%) and written language (46.7%) (Spiel et al., 2014, see their Table 3). These academic problems in the core school subjects mathematics and English language were more common than assignment completion (40%), problems in organization (38.3%), social skills and peer problems (35%), compliance (26.7%) and verbal communication (20%). There was some variation between schools depending on the method of problem identification, but mathematics and language were consistently the most important problems and the top targets in plans for improvement.

Another study (Marshall et al., 1997) found that in 6- to 12-year-old pupils with ADHD who only showed inattention, mathematical skills were lower than in pupils with inattention and hyperactivity, while reading scores were not. While this study did not use a control group of mainstream pupils for comparison, data showed that the weakness in mathematics could have been caused by a comparably lower performance IQ (Marshall et al., 1997, see their Table 1). Thus, there can be differences between language and mathematical skills in pupils with ADHD, but further research is needed to find whether there would be systematic differences between the two school subjects.

Longitudinal research showed that also mainstream pupils' goalsetting in mathematics was declining during adolescence in relation to their achievements, however, no comparison to a language subject, or with pupils with ADHD was made (Scherrer et al., 2020). Maladaptive achievement strategies such as task avoidance are relatively stable over time (r=.62) in pupils with ADHD and mediate school grades (Palmu et al., 2023). School grades are so important that they determine the level of pupils' life satisfaction (Lettau, 2021), future interests but not vice versa (Von Maurice et al., 2014) and mediate effects of competencies (Schurtz et al., 2014).

Some authors could show that between 7 and 19 years, ADHD symptoms decrease (e.g. Döpfner et al., 2015). Other research revealed that while there was a constant difference to mainstream pupils in rash and risky decision-making strategies, there was no evidence that ADHD would peak in adolescence (Dekkers et al., 2022). These authors conclude that there is a need for a developmental perspective. On the one hand, school grades and achievement may have a reciprocal relationship (Scherrer et al., 2020), and pupils in secondary schools may become more anxious to achieve, especially in mathematics (Hill et al., 2016). On the other hand, anxiety can potentially diminish some aggressive ADHD symptoms in adolescence (Murray et al., 2018).

The current study

The current study aims to assess whether ADHD has a constant or diminishing association with grades in secondary schools using longitudinal data of two cohorts, each gathered over a period of three years. We did not study pupils with ADHD and a more severe additional diagnosis that may have warranted attendance of a special school, but only adolescents attending regular schools. We investigated data from participants with and without ADHD from two cohorts of two longitudinal projects. In both projects, these regular schools had pupils with SEND, but while in COHORT 1, this was not part of the participation requirement in the project, having pupils with SEND in the classroom was a requirement for participation in the second project with COHORT 2 (Schmitt et al., 2023). We will use the term 'mainstream' to refer to pupils without ADHD, but not for the type of school.

We investigated school grades in mathematics and language of adolescents with and without ADHD, in two longitudinal samples from Germany attending secondary schools. In each of the two longitudinal samples, we matched pupils with an ADHD diagnosis with comparison pupils by age in months because being of young age in class plays a role for ADHD (e.g. Bonati et al., 2018; Zoëga et al., 2012) and by gender as there is usually a preponderance of boys in ADHD samples in Western countries (e.g. Lecendreux et al., 2011; Wichstrøm et al., 2012), but for instance, not in India (Joshi, & Angolkar, 2021).

It should be noted that although ADHD and dyslexia are separate diagnoses, symptoms of ADHD such as inattention ($r=-.42$), hyperactivity ($r=-.30$) and inhibition ($r=-.28$) can affect reading ability (Battistutta et al., 2021). In the study of Battista et al., of 34 adolescents with ADHD, 10 had a diagnosis of both ADHD and dyslexia which is equivalent to 29.4% or nearly one third of the sample. Another study compared the effects of reading training and parent training on ADHD in primary school pupils (Tamm et al., 2017). They could show that parent training improved primary school children's ADHD but not their reading, while reading training improved their language skills but not their ADHD symptoms. A combined parent and reading training improved each of these two training domains simultaneously, but not above the level achieved by single treatments. This result confirmed that ADHD and dyslexia are separate problems. Thus, in the current study we controlled for a comorbid dyslexia diagnosis. In the following, we use the term dyslexia for reading and writing difficulties mainly for the reason of having a short and concise concept, without any implications of causes or severity.

An achievement gap in language and mathematics in pupils with ADHD compared to pupils without ADHD is already present during primary school (Silva et al., 2020). Based on the previous research, the following hypotheses for secondary school pupils with ADHD are: (1) There is an achievement gap in language and mathematics grades when controlled for dyslexia, (2) the achievement gap is larger in mathematics than in language, and (3) the longitudinal data allowed to test whether the achievement gap narrowed in secondary school.

Method

Participants

This study analyses data from two nationwide projects with longitudinal designs (Schmitt et al., 2023; Thums et al., 2023). The longitudinal data of COHORT 1 was collected in 2012, 2013 and 2015 (NEPS Network, 2024), while the longitudinal data of COHORT 2 was collected in 2019, 2020 and 2022. Measurement points are labelled as T1, T2 and T3. The gap occurred because of the COVID epidemic. In the year 2021 no data was collected for COHORT 2 because public life came to a standstill during COVID-19, with frequent local school closures following COVID-19 infections. During this time, behavioral changes occurred not only in children with ADHD, but also in control groups with increased restlessness, aggressiveness, and anxiety (Tessarollo et al., 2022). Accordingly, we matched the unequal intervals of the period 2019, 2020 to 2022 with those of the earlier COHORT 1 from the years 2012, 2013 and 2015. In the longitudinal COHORT 1, pupils did not experience school closures. In both studies, the participating schools were distributed across all federal states of Germany, except for Berlin and Brandenburg because the latter had six years of obligatory primary school (Senatsverwaltung, 2023), while in the other federal states secondary school starts in Year 5 (Grellmann, & Edelstein, 2017).

COHORT 1 is a nationwide representative longitudinal project (Thums et al., 2023), while in COHORT 2, only schools with pupils with SEND were included (Schmitt et al., 2023). In COHORT 1, there were $N=5773$ pupils and in COHORT 2, there were $N=3385$ pupils in the original data sets. Data about ADHD was not available in all cases. In COHORT 1, the ADHD rate was 4.1% (141 of 3420); in COHORT 2, the ADHD rate was 2.9% (98 of 3385). These rates are comparably low (Ayano et al., 2023). In Germany, ADHD is an official diagnosis that can only be made by pediatricians, clinical psychologists, or a school psychology service. We did not have access to information about whether the adolescents were on stimulant medication, but it should be assumed that for many adolescents this was the case as a recent pharmaco-epidemiological study reported that in Germany, ADHD is medicated from age 6 to age 20 (Grimmsmann, & Himmel, 2021). These authors report that in 2012, more than a million children and adolescents under the age of 17 were on a daily medication. While the ADHD medication trend until 2018 was declining in minors, it was slowly and gradually rising in adults. Some patients get ADHD medication as an intervention but not as a continuous treatment.

We identified $n=226$ adolescent participants with ADHD in the two cohorts with data for school grades. We were able to match $n=184$ of these adolescents with ADHD to control participants based on their age in months, sex, and dyslexia. The analysis sample included $N=368$ ADHD- and non-ADHD participants; 198 of them were part of COHORT 1 and 170 were part of COHORT 2. There were 28 girls (28.3%) in COHORT 1 and 18 girls (21.2%) in COHORT 2, in both the mainstream and the ADHD group.

Dyslexia The dyslexia variable is an aggregate variable that includes pupils who either had a writing disorder, a reading disorder, or a reading and writing disorder. Among the ADHD group in COHORT 1, there were 20 participants (20.2%) with dyslexia and 79 (79.8%) participants without dyslexia. Due to the matching procedure, the same was true for the control group within COHORT 1. Average age in months of COHORT 1 sample was $M=12;6$ (years; months) and, accordingly, a t-test (two-tailed) for independent samples in the two cohorts showed that the age of pupils with and without ADHD did not differ significantly, $p > .926$. In COHORT 2, there were 20 participants (23.5%) with dyslexia and 65 (76.5%) without dyslexia in both the ADHD and the control group. The average age of the COHORT 2 sample was $M=12;10$ (years; months) and, likewise, the age of the pupils with and without ADHD did not differ significantly, $p > .972$.

A variable with four groups was created for both cohorts, namely, mainstream pupils in Group 1, mainstream pupils with Dyslexia in Group 2, pupils with ADHD in Group 3, and pupils with ADHD and dyslexia in Group 4. The data about the age of participants in the four groups can be found in Table 1.

Table 1 Participant age per cohort and group (Years; Months)

Group	*n*	*Min*	*Max*	*M*	*SD (in months)*
COHORT 1 (*N*=198)					
Mainstream, no Dyslexia	79	11;9	14;8	12;10	9
Mainstream, Dyslexia	20	11;10	13;10	12;11	7
ADHD, no Dyslexia	79	11;9	14;8	12;10	9
ADHD and Dyslexia	20	11;10	13;11	12;11	7
COHORT 2 (*N*=170)					
Mainstream, no Dyslexia	65	11;10	14;8	12;10	9
Mainstream, Dyslexia	20	11;9	13;11	12;10	7
ADHD, no Dyslexia	65	11;10	14;8	12;10	9
ADHD and Dyslexia	20	11;9	13;11	12;10	7
Total *N*	368				

The sub-samples were matched for age, gender and dyslexia

Measures

School type In Germany, three types of vocational versus academically oriented selective schools co-exist during secondary school age that are usually geographically separate, or they are run as educational tracks in parallel in comprehensive schools with a more flexible system that houses all three tracks under one roof. There is the vocational 'Hauptschule' that ends after year 9, the administratively oriented 'Realschule' that ends after year 10, and the academic 'Gymnasium' or high school that awards the Abitur, after year 12 or 13, similar in nature to the International Baccalaureate, which allows for university access. Thus, a dichotomous variable 'other school'/'high school' was created.

Pupils of the current COHORT 1 were more likely to attend high school. COHORT 1 had a relatively high proportion of pupils attending high school (30.3%), and this was the same in both pupils with and without ADHD because for COHORT 1, we used the dichotomous variable to counterbalance the ADHD and the control sample. In COHORT 2, only eight pupils (4.7%) attended high school, and only two of those were pupils with ADHD. Hence, while in COHORT 1, the frequency of pupils attending high school was balanced across ADHD occurrence, in COHORT 2, the number of pupils attending high school was negligible.

School grades For COHORT 1, end-of-year grades for language and mathematics were available in both subjects in Year 6 and 7, and half-year grades were available for Year 9. Grades were self-reported by pupils in a questionnaire. For COHORT 2, half-year school grades in mathematics and language were available. Only in Grade 9, also the end-of-year marks could be obtained which in the larger sample correlated with the half-year marks for language and mathematics $r=.81$, $p<.001$, $n=1268$, and $r=.78$, $p<.001$, $n=1224$, respectively. Thus, it can be assumed that the half-year grades are reliable in terms of children's performance.

Some schools used points, but most used the more traditional scale with 1 for the best mark and 6 for the worst mark. Grades that used point systems were recoded into the common and well-known grading scale from 1 to 6 using publicly available conversion tables, see conversion Table 'Unter- und Mittelstufe' [Lower and Upper Tier] agreed by all Bundesländer on the 3rd October 1968, https://de.wikipedia.org/wiki/Schulnote. A grade of 1 is very good (15−13 points), 2 is good (12−10 points), 3 is satisfactory (9−7 points), 4 is sufficient (6−4 points), 5 is a fail (3−1 points) (with compensation opportunity by better grades in other subjects when considering progression) and 6 is a fail (0 points) (without compensation opportunity). Further grade qualifications, for instance, through an asterisk or a plus/minus were not taken into account.

Parental education The parents' education was measured with the Comparative Analysis of Social Mobility in Industrial Nations (CASMIN) index which provides an internationally comparable indicator of educational achievement (Brauns et al., 2003). In the present study, we have been using the highest CASMIN score reported by the parents. A t-test for independent samples (two-tailed) showed that when comparing the CASMIN score of the ADHD samples with their control groups, there was no difference, $p_s = 0.821$.

Migration Available background data on migration indicated that it occurred in 10.6% of COHORT 1, but in 22.9% of COHORT 2. This data is tentative as 9.6% of the participants of COHORT 1 and 6.5% of the participants of COHORT 2 did not give information on their migration background. When comparing the ADHD and control groups per cohort, there was no difference in migration backgrounds, $p_s > 0.681$.

Statistical analyses

Because some students did not provide information on their grades or they did not participate at a given point, some missing values were observed. For language grades, there were between 8.15% and 37.77%, while for the mathematics grade, there were between 8.97% and 37.50% of missing data. It is normal that in longitudinal studies, missing data appear especially at the later points of measurement and hence listwise deletion of cases with missing data is not a good viable option (Jelicić et al., 2009). The ADHD samples were selective and thus not randomly recruited, and the control samples were matched but randomly recruited, thus the most appropriate method was deemed to be missing values imputation (Griswold et al., 2021; Huque et al., 2018).

Missing values of the focal variables were imputed one hundred times with classification and regression trees using chained equations in R with the *mice* package (Version 3.16.0; Van Buuren, & Groothuis-Oudshoorn, 2011). In addition to the variables school type and ADHD status, several other variables were included in our imputation model of the school grades to improve the accuracy of the multiple imputed data, that is, the pupils' age, gender (girl versus boy), migrant background (no versus yes), country of birth (Germany versus other), comorbidity with dyslexia (no versus yes), and the highest parental education as measured by the CASMIN score (Brauns et al., 2003). Imputations of school grades were conducted independently for the COHORT 1 and COHORT 2 samples using Rubin's rule (Rubin, 1987).

Procedure

The data collection of cohorts 1 and 2 was approved by the education resp. culture ministries of the Bundesländer. All schools, teachers, and parents on behalf of their pupils had consented to voluntary participation in the project. They received a data protection sheet detailing their rights to refuse participation without disadvantage. The data collection was outsourced to the International Association for the Evaluation of Educational Achievement (IEA) (Stichting I.E.A. Secretariaat Nederland), Hamburg branch, Germany.

For COHORT 1, school grades were reported by pupils in questionnaires in the classrooms under supervision of the respective schools. A feasibility study for the project of COHORT 1 showed that in grade 5, pupils could reliably report their and their parents' country of birth with 0.85-0.87 agreement and their native language with 0.95-0.97 while pupils with SEND showed reliabilities of 0.67-0.95 for these variables (Nusser et al., 2016). These authors state that reliability depends on linguistic demands and complexity of items. Thus, to write down two numbers which are the grades for the core subjects language and mathematics under supervision in the classroom was not too demanding for secondary school pupils.

At the first and second measurement points, the assessments in the schools took place in the first half of each school year, between the months of November and January. At the third measurement point, the assessment in the schools took place in the second half of the school year. Before being sent to the schools, all survey administrators underwent extensive training. The data on the ADHD diagnosis and dyslexia were obtained from questionnaires addressed to the parents.

For COHORT 2, school coordinators filled in questionnaires detailing, for instance, pupils' school grades, SEND certificate, types of support etc. The second point of data collection (T2) occurred during the COVID-19 epidemic. Half-term school grades from before the onset of the epidemic in spring 2020 were entered as planned in summer, but questionnaires of 541 pupils (20.85% of N) were sent by mail to those schools that were closed because of infected pupils or staff. The third point of data collection (T3) was carried out only in the school context, as before at T1.

Results

The imputed and pooled data were analyzed for differences of group means in school grades in language and mathematics between pupils with ADHD versus the age-, gender-, and dyslexia matched control group in each cohort in SPSS 28.0 using univariate t-tests. Visualizations of group means across imputations were produced with SAS JMP Pro version 17.2.0. The exact group means for language and mathematics grades of the imputed and the pooled data, per cohort and group as in Table 2, can be found in Table S1.

The t-tests are followed up by path models of school grades that included parent background variables which may influence school grades. They were carried out with SPSS AMOS 28.0 Graphics. The raw data without imputations were used for the path models because AMOS acknowledges the missing values using full information maximum likelihood estimation.

Differences in school grades of adolescents with and without ADHD were compared within each year group per cohort. Table 2 lists the results of the language grades of COHORT 1 and COHORT 2, first for the t-tests for the complete sample, followed by the respective sub-samples of pupils without and those with Dyslexia. To correct for multiple testing, only highly significant *p*-values, $p<.001$, are set in bold in the Tables.

Table 2 shows that with respect to the differences in language grades in COHORT 1, none of the comparisons between pupils with and without ADHD reached the stringent adjusted criterion of the high p-value of 0.001, but there are several comparisons which fall just short of $p=.05$. This was not the case for COHORT 2: Differences between pupils with and without ADHD, both in the total sample and in the subsample of pupils without dyslexia, were significant at each measurement point. In pupils with dyslexia, this was only the case in Year 6.

Figure 1 visualizes the distribution of the means in the two cohorts. The upper left graph of COHORT 1 values shows indeed a small but constant gap, with pupils with ADHD showing somewhat lower language grades. The grades of pupils with dyslexia did not show a constant and clear gap and were not significantly different because of ADHD.

The gap in COHORT 2 was much larger than in COHORT 1, see Fig. 1, upper graphs, as already indicated by the significant p-values in Table 1. COHORT 2, upper right, shows significant differences in all three secondary school years, with the mainstream pupils obtaining better language marks than pupils with ADHD. However, when pupils had

Table 2 Longitudinal trajectories of differences in language grades between adolescents without and with ADHD ($N = 368$)

							CI
Year	*t*	*df*	*p*	*M Diff*	*SE*	Lower	Upper
COHORT 1 (*n* = 198)							
6	−1.60	13195	.109	−0.18	0.11	−0.41	−0.04
7	−1.93	9364	.054	−0.23	0.12	−0.46	−0.00
9	−1.95	3984719	.051	−0.24	0.12	−0.48	−0.00
COHORT 1, no Dyslexia (*n* = 158)							
6	−2.15	15668	.030	−0.28	0.13	−0.53	−0.03
7	−1.78	11569	.079	−0.21	0.12	−0.44	0.02
9	−1.66	13288026	.097	−0.22	0.13	−0.49	0.04
COHORT 1, Dyslexia (*n* = 40)							
6	−0.68	19526	.494	−0.17	0.25	−0.33	0.67
7	−0.87	29596	.384	−0.29	0.33	−0.94	0.36
9	−1.02	444565	.309	−0.30	0.29	−0.88	0.28
COHORT 2 (*n* = 170)							
6	**−11.67**	**3004580**	**.001**	**−1.45**	**0.12**	**−1.70**	**−1.21**
7	**−6.09**	**581**	**.001**	**−1.00**	**0.16**	**−1.31**	**−0.67**
9	**−3.68**	**523**	**.001**	**−0.70**	**0.19**	**−1.07**	**−0.32**
COHORT 2, no Dyslexia (*n* = 130)							
6	**−11.08**	**-**	**.001**	**−1.54**	**0.14**	**−1.81**	**−1.27**
7	**−6.70**	**638**	**.001**	**−1.22**	**0.17**	**−1.56**	**−0.88**
9	**−4.24**	**493**	**.001**	**−0.90**	**0.21**	**−1.32**	**−0.48**
COHORT 2, Dyslexia (*n* = 40)							
6	**−5.69**	**69167**	**.001**	**−1.17**	**0.20**	**−1.57**	**−0.77**
7	−0.85	795	.394	−0.25	0.30	−0.84	0.33
9	−0.09	461	.925	−0.04	0.38	−0.78	0.78

M Diff Difference in means between groups, *SE* Standard error of *M Diff*. *CI* 95% confidence interval for *M Diff*. The values of significant *t*-tests are set in bold

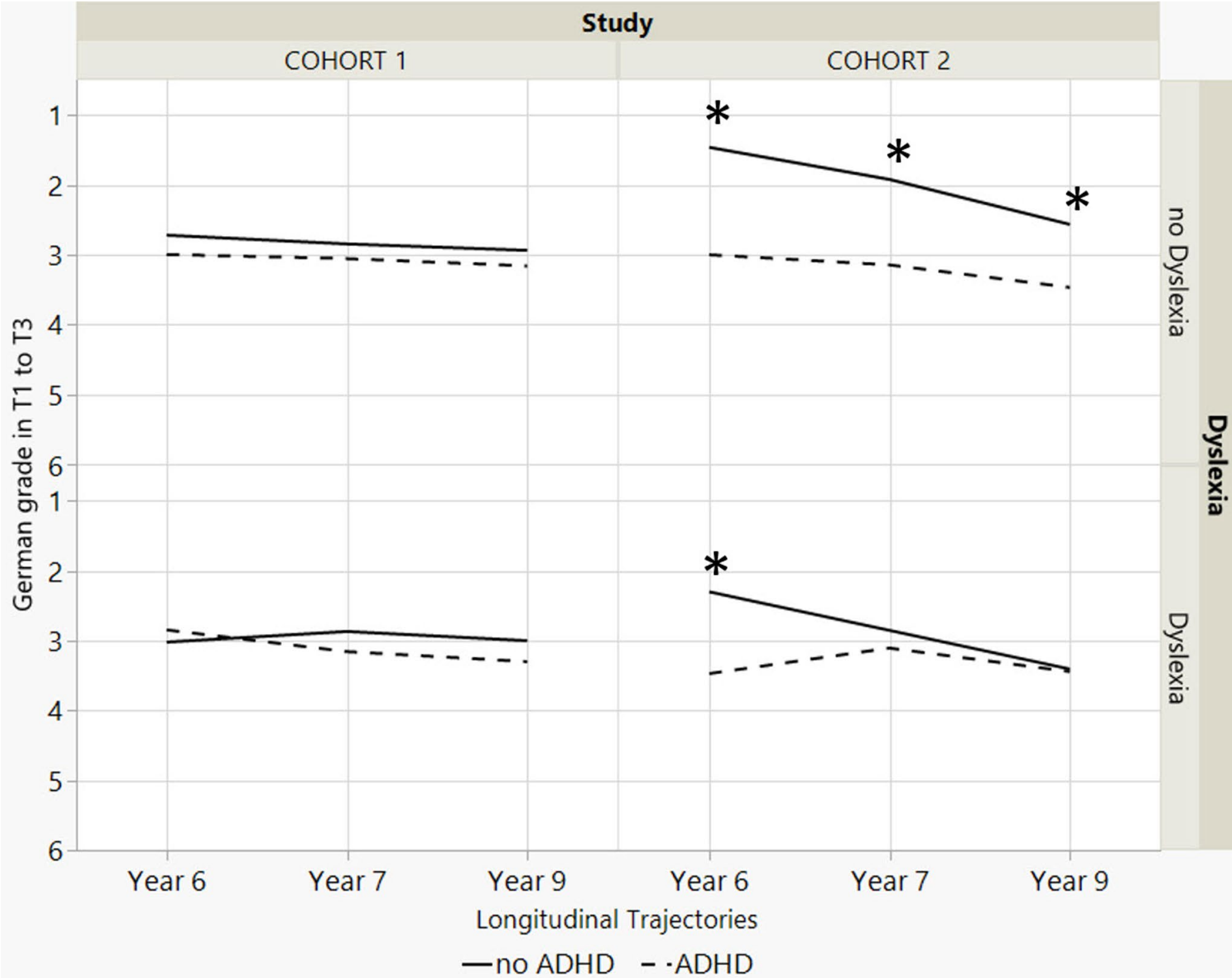

Fig. 1 Longitudinal trajectories of language grades for pupils with and without ADHD, controlled for Dyslexia

dyslexia, lower right-hand side, this comparison was only significant in Year 6. In short, the control for dyslexia in the comparison of mainstream pupils and those with ADHD yielded constant and consistent differences at the three measurement points T1 to T3 as pupils with ADHD constantly showed comparably lower language grades.

The same statistical procedure was repeated with the school grades in Mathematics. Table 3 shows that for COHORT 1, few comparisons reached significance at $p<.05$ and none of them were significant according to the adjusted p-value of 0.001. For COHORT 2, there were significant differences in Mathematics grades between pupils with and without ADHD at T1 and T2 but not T3 when adjusted for multiple testing. Again, when controlled for dyslexia, for COHORT 2 only the comparison in Year 6 was significant.

The visualization in Fig. 2 conveys a very similar picture to Fig. 1 insofar as the school grades of pupils with ADHD are constantly lower than of those pupils without ADHD, but significantly so only in COHORT 2 where the gap is larger. In COHORT 2, significantly lower grades in Mathematics for pupils with ADHD did not show at the last point of measurement due to the stringent adjusted p-level.

In short, in COHORT 1 the consistent gap in school grades between pupils with and without ADHD was small and the p-values did not reach statistical significance, while in COHORT 2, the gap was larger and significant for both school subjects.

Individual differences

In a second set of statistical analyses, we controlled the results for further variables that could play a role in school grades besides ADHD. This was especially relevant because COHORT 2 had fewer participants on an academic school track. Participants who were dyslexic were not considered in

Table 3 Longitudinal trajectories of differences in mathematics grades between mainstream adolescents and those with ADHD (N=368)

						CI	
Year	*t*	*df*	*p*	*M Diff*	*SE*	Lower	Upper
COHORT 1 (n=198)							
6	−1.37	13,654	0.171	−0.20	0.14	−0.48	−0.09
7	−1.62	19,369	0.106	−0.23	0.14	−0.51	−0.05
9	−1.90	4,903,613	0.058	−0.29	0.15	−0.58	−0.01
COHORT 1, no Dyslexia (n=158)							
6	−2.09	11,833	0.036	−0.34	0.16	−0.65	−0.03
7	−2.21	23,014	0.027	−0.34	0.16	−0.65	−0.04
9	−1.43	-	0.153	−0.24	0.17	−0.57	−0.09
COHORT 1, Dyslexia (n=40)							
6	−1.06	7023	0.291	0.35	0.33	−0.30	1.00
7	0.69	26,922	0.488	0.23	0.33	−0.41	0.86
9	−1.41	188,026	0.158	−0.47	0.33	−1.11	0.18
COHORT 2 (n=170)							
6	**−5.42**	**502,626**	**0.001**	**−0.86**	**0.16**	**−1.17**	**−0.55**
7	**−3.20**	**549**	**0.001**	**−0.58**	**0.18**	**−0.93**	**−0.22**
9	−2.51	564	0.012	−0.57	0.23	−1.02	−0.12
COHORT 2, no Dyslexia (n=130)							
6	**−4.39**	**862,009**	**0.001**	**−0.83**	**0.19**	**−1.20**	**−0.46**
7	**−3.49**	**480**	**0.001**	**−0.71**	**0.20**	**−1.11**	**−0.31**
9	−2.38	449	0.018	−0.64	0.27	−1.16	−0.11
COHORT 2, Dyslexia (n=40)							
6	**−3.42**	**122,344**	**0.001**	**−0.96**	**0.28**	**−1.52**	**−0.41**
7	−0.42	1638	0.674	−0.15	0.35	−0.83	0.54
9	−0.76	596	0.447	−0.36	0.46	−1.28	0.56

M Diff Difference in means between groups, *SE* Standard error of *M Diff*. *CI* 95% confidence interval for *M Diff*. The values of significant *t*-tests are set in bold

the model. Grades at T1 to T3 were the endogenous variables and ADHD, gender differences (Sex), a different cultural background as indicated by another language spoken at home (Migration) and the CASMIN score for years of parental education (ParentEdu) were the exogenous variables, see Fig. 3.

The exogenous variables were not significantly correlated with each other, p_s >0.096 and thus no paths were added between them.

Language Table 4 lists the statistical results for language grades of the two cohorts. Table 4 as well as the following Table 5 report the contingency between the school grades at T1 and T2 as well as T2 and T3, thus testing the longitudinal progression in one model. Further below in Table 4, the significance of the exogenous variables (unstandardized and standardized weights) is listed per point of measurement. It can be ascertained whether parental background variables or ADHD and gender of pupils showed a closer association with grades at the earlier or rather at the later points of measurement. Significant statistical results are set in bold.

Because of the four exogenous variables, the quoted RMSEA value refers to an independence model (Shek, & Yu, 2014). For COHORT 1, the chi-square value was 26,831 with 7df and a probability level of p<.001 (RMSEA=0.15, p<.001), while for COHORT 2, the chi-square value was 2,656 with 7df and a probability level of 0.915 (RMSEA=0.22, p<.001). For both samples, the transition probabilities T1-T2 (Year 6 to 7) and T2-T3 (Year 7 to 9) are significant. Moreover, at T1, there are significant differences between language grades of pupils with ADHD in both cohorts. However, in COHORT 2, ADHD is a significant factor not only at T1 but also at T2, but is no longer significant at T3.

While in COHORT 1 there are only individual differences at T3, in COHORT 2 there are continuously some significant individual differences to consider. There are sex differences, parent education and migration at T1 and T2, but only one significant factor at T3, namely migration.

Mathematics The same path models were carried out for the grades in mathematics, see Table 5. For COHORT 1, the chi-square value was 4,401 with 7df and a probability level of 0.733 (RMSEA=0.16, p<.001), while for COHORT 2, the chi-square value was 7,155 with 7df and a probability level of 0.413 (RMSEA=0.13, p<.001).

As for the language grades, there are again significant transition probabilities for T1-T2 and T2-T3 for grades, and

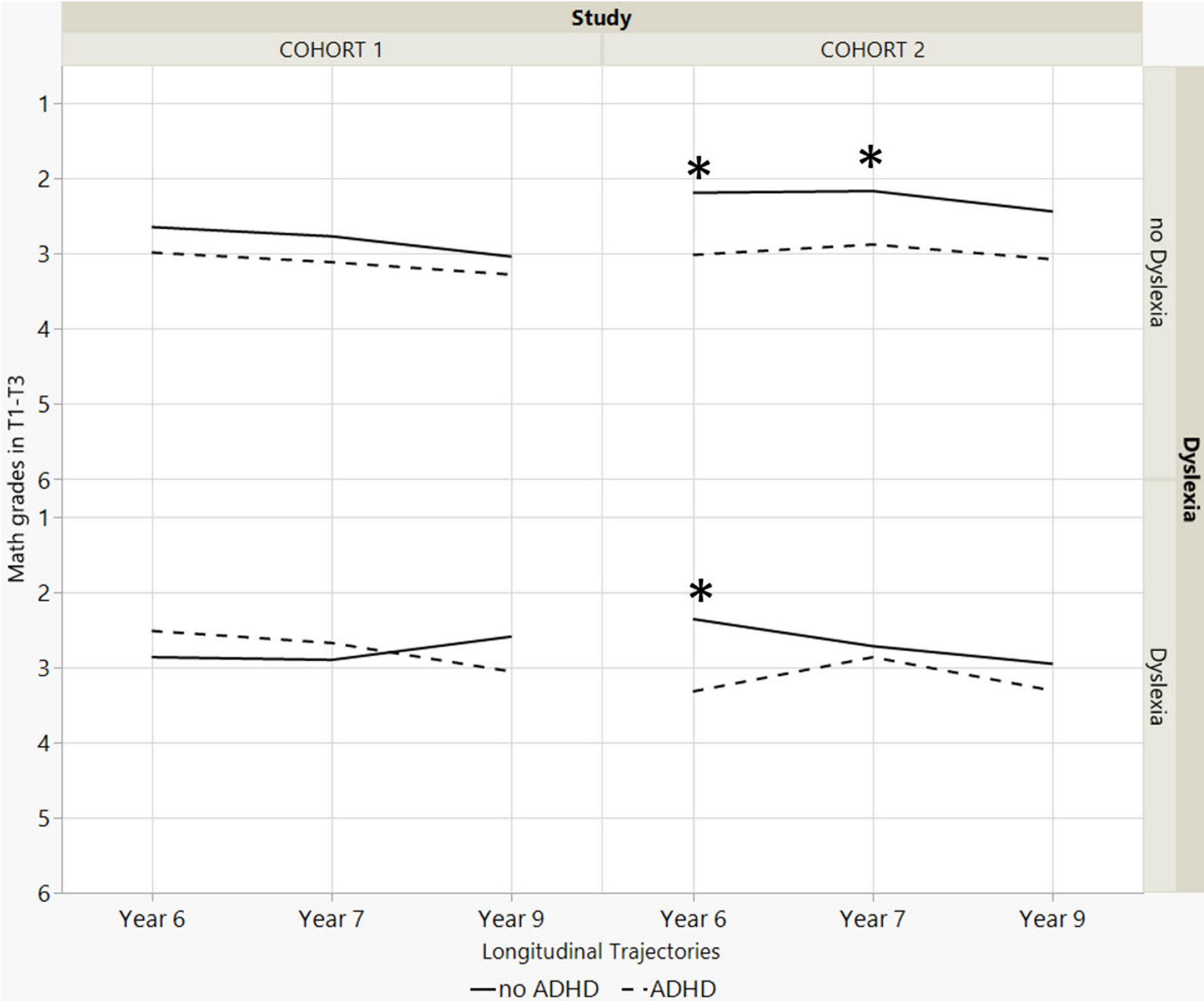

Fig. 2 Longitudinal trajectories of math grades for pupils with and without ADHD, controlled for Dyslexia

ADHD is again significant at T1 in both cohorts. ADHD in COHORT 2 is again significant at both T1 and T2 but not at T3.

However, different to language grades, individual differences in mathematics grades are much reduced. In COHORT 1, there are no individual differences. In COHORT 2, gender differences at T3 have become significant along with migration.

Discussion

The current study analyzed school grades of two longitudinal cohorts of adolescent pupils with and without ADHD from two longitudinal nationwide German studies, controlled for dyslexia. An achievement gap in language and mathematics in pupils with ADHD can be already present during primary school (Silva et al., 2020). We had the following hypotheses for secondary school pupils with ADHD. First, there is an achievement gap in language and mathematics grades when controlled for dyslexia. Second, the achievement gap may be more likely to occur in mathematics than in language. Third, because ADHD symptoms may diminish in adolescence, the longitudinal data allow to test whether this achievement gap has narrowed on the third measurement occasion. Our research indicates that if dyslexia is absent from both students with ADHD and those in the control group, the expected achievement gap in school grades is more likely to become apparent. We could confirm, using path modeling, that the association of ADHD with school grades diminished during adolescence. This occurred earlier in COHORT 1 – in Year 7 - than in COHORT 2 where ADHD was no longer significant in Year 9, in both school subjects. COHORT 1 also showed fewer

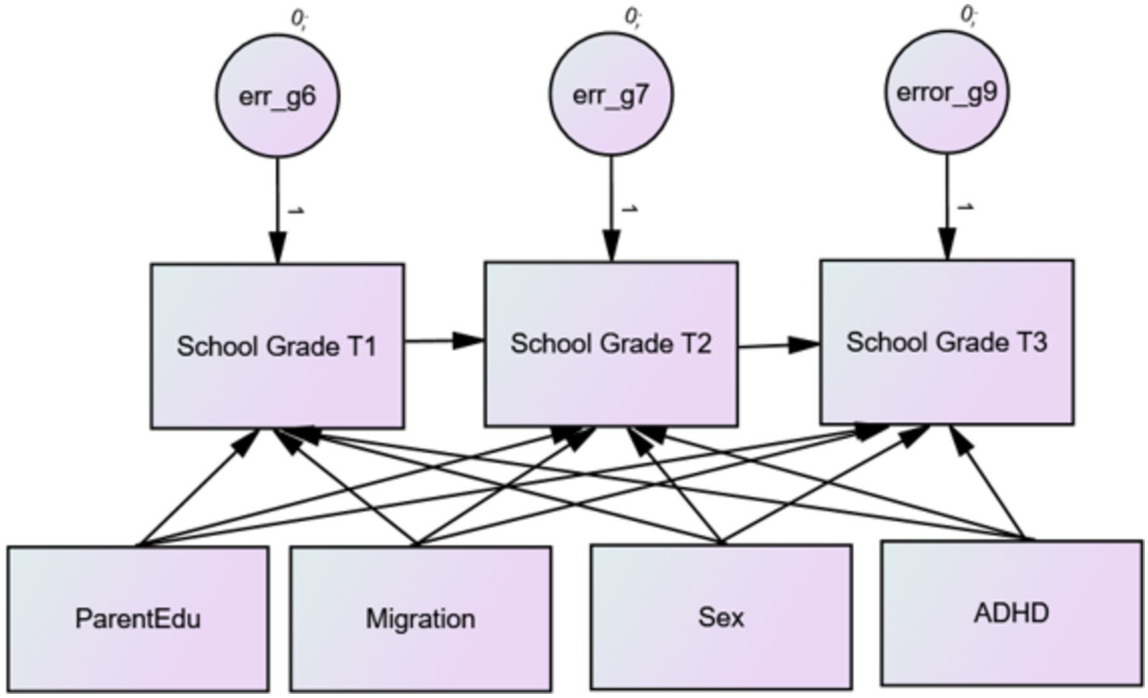

Fig. 3 Path model of longitudinal school grades

individual differences in school grades because of the gender of the adolescents, parental education and migration background than in COHORT 2 during the course of secondary school.

The first hypothesis of our study was that there would be an achievement gap in language and mathematics grades when controlled for dyslexia. In COHORT 1, there was only a small but constant achievement gap that did not reach significance given the correction for multiple t-testing. In COHORT 2, however, a large achievement gap was present in the grades of both subjects at the first two points of measurement but the association with ADHD was waning as reflected in diminishing t-values. In this cohort, other factors became significant at T3. The sign of the Maximum Likelihood Estimate for sex differences was rather positive in language (T1 = 0.25, T2 = 0.34, T3 = −0.03) but negative in mathematics (mathematics T1 = −0.10, T2 = −0.12, T3 = −0.82) and became significant at T3 in mathematics in addition to migration background. This shows the well-known yet often inconsistently found disadvantage of girls in mathematics (e.g. Weijer-Bergsma et al., 2022; Yu et al., 2024). Also, in our two cohorts, sex differences were not consistent because in COHORT 1, sex differences in mathematics were never a significant factor.

In COHORT 1, although less riddled by individual differences, sex and parents' education were new significant factors in language grades at T3. Towards the end of secondary school, when the curriculum becomes more challenging and examined, parents may exert more influence on pupils achievements as their grades would determine the type of educational pathway they could take, in particular access to higher education (Helbig et al., 2025). However, they found that in the years after the final secondary school exams, the importance of parental influence was diminished again.

The second hypothesis was that the achievement gap may be more likely to occur in mathematics than in language. In previous research, performance levels below benchmarks by pupils with ADHD were more likely to show in mathematics than in reading at primary school (Silva et al., 2020). Also in secondary school pupils, mathematics was more often a target for improvement than reading (Spiel et al., 2014, see their Table 3). This hypothesis of a selective deficit in mathematics grades could not be confirmed here because in both cohorts, there were similar achievement gaps in grades for both language and mathematics. A general achievement gap in school grades in pupils with ADHD is in accordance with other previous ADHD research, though, where a general deficit in behavioral compliance (Becker et al., 2023) and motivation (Palmu et al., 2023) as well as cognitive speed (Fredrick et al., 2020) was seen as responsible for lower school grades.

The third hypothesis was that because ADHD symptoms may diminish in adolescence, the longitudinal data could show whether this achievement gap has narrowed on the third measurement occasion. A reduced association of ADHD with school grades could be clearly confirmed by the path modeling in both cohorts as ADHD was no longer significant at T2 and T3 in COHORT 1 and at T3 in

Table 4 Longitudinal path models for Language grades for COHORTS 1 and 2

Path	Unstandardized Regression Weights	SE	*p*	Standardized Regression Weights
COHORT 1				
Longitudinal Results (School Years)				
Language 6 ->7	**0.48**	**0.07**	**0.001**	**0.54**
Language 7 ->9	**0.56**	**0.08**	**0.001**	**0.46**
Individual Differences T1-T3				
Year 6 (T1)				
ADHD	**0.31**	**0.13**	**0.017**	**0.19**
Sex	0.04	0.15	0.779	0.02
Parent Edu.	−0.06	0.03	0.091	−0.14
Migration	0.28	0.21	0.190	0.11
Year 7 (T2)				
ADHD	0.05	0.10	0.620	0.04
Sex	0.10	0.11	0.924	0.07
Parent Edu.	0.00	0.03	0.126	0.01
Migration	0.08	0.16	0.468	0.04
Year 9 (T3)				
ADHD	0.11	0.12	0.927	0.06
Sex	**0.29**	**0.13**	**0.024**	**0.15**
Parent Edu.	**−0.07**	**0.03**	**0.015**	**−0.17**
Migration	−0.31	0.19	0.099	−0.12
COHORT 2				
Longitudinal Results (School Years)				
Language 6 ->7	**0.33**	**0.10**	**0.001**	**0.36**
Language 7 ->9	**0.71**	**0.26**	**0.006**	**0.64**
Individual Differences T1-T3				
Year 6 (T1)				
ADHD	**1.48**	**0.13**	**0.001**	**0.69**
Sex	0.25	0.15	0.083	0.10
Parent Edu.	**−0.12**	**0.03**	**0.001**	**−0.28**
Migration	**0.35**	**0.15**	**0.016**	**0.14**
Year 7 (T2)				
ADHD	**0.95**	**0.20**	**0.001**	**0.47**
Sex	**0.34**	**0.16**	**0.034**	**0.15**
Parent Edu.	**−0.09**	**0.03**	**0.004**	**−0.23**
Migration	−0.26	0.16	0.115	−0.11
Year 9 (T3)				
ADHD	0.13	0.47	0.777	0.06
Sex	−0.03	0.35	0.931	.−0.01
Parent Edu.	−0.07	0.07	0.294	−0.17
Migration	**0.74**	**0.32**	**0.022**	**−0.29**

Table 5 Longitudinal path model for mathematics grades for COHORTS 1 and 2

Path	Unstandardized Regression Weights	SE	*p*	Standardized Regression Weights
COHORT 1				
Longitudinal Results (School Years)				
Mathematics 6 ->7	**0.57**	**0.07**	**0.001**	**0.59**
Mathematics 7 ->9	**0.69**	**0.07**	**0.001**	**0.62**
Individual Differences T1-T3				
Year 6 (T1)				
ADHD	**0.34**	**0.16**	**0.033**	**0.17**
Sex	−0.18	0.18	0.327	−0.08
Parent Edu.	−0.07	0.04	0.095	−0.14
Migration	0.02	0.26	0.068	0.01
Year 7 (T2)				
ADHD	0.16	0.13	0.223	0.08
Sex	−0.06	0.14	0.661	−0.03
Parent Edu.	−0.03	0.03	0.328	−0.07
Migration	−0.01	0.21	0.966	0.04
Year 9 (T3)				
ADHD	0.00	0.13	0.975	0.00
Sex	0.10	0.15	0.527	0.04
Parent Edu.	0.01	0.04	0.271	0.02
Migration	−0.26	0.22	0.225	−0.08
COHORT 2				
Longitudinal Results (School Years)				
Mathematics 6 ->7	**0.38**	**0.09**	**0.001**	**0.46**
Mathematics 7 ->9	**0.89**	**0.19**	**0.001**	**0.73**
Individual Differences T1-T3				
Year 6 (T1)				
ADHD	**0.73**	**0.18**	**0.001**	**0.33**
Sex	−0.10	0.21	0.632	−0.04
Parent Edu.	**−0.14**	**0.04**	**0.001**	**−0.31**
Migration	0.22	0.21	0.288	0.09
Year 7 (T2)				
ADHD	**0.54**	**0.18**	**0.003**	**0.29**
Sex	−0.12	0.20	0.550	−0.06
Parent Edu.	−0.03	0.04	0.468	−0.08
Migration	0.37	0.20	0.064	−0.18
Year 9 (T3)				
ADHD	−0.30	0.33	0.369	−0.13
Sex	**−0.82**	**0.34**	**0.015**	**−0.32**
Parent Edu.	−0.03	0.07	0.656	−0.07
Migration	**−0.99**	**0.34**	**0.004**	**−0.39**

COHORT 2. This result of our current investigation speaks to the success of teaching adolescents with ADHD in secondary tier schools (Ward et al., 2022). Academic school grades reflect not only assessments of pupils' competencies, but also include evaluations of behavioral aspects such as completion of assignments, participation in classroom discussions, and attention to the instructions that potentially can be influenced by specific teaching methods. For instance, Australian teachers used intrinsic, intuitive, and inclusive (3I's) ways of working and reported that students felt supported (Carter et al., 2023). When pupils with ADHD feel depressed or anxious this may also have repercussions on their academic achievements in mathematics and language (Visser et al., 2020a, b). The well-being of pupils may be addressed with implicit ways of teaching rather than following explicit guidelines (Sonneck et al., 2021). In this way, pupils may acquire academic buoyancy resp. self-efficacy during secondary school (Weißenfels et al., 2023) which

could lessen the association of ADHD with school grades at the beginning of secondary school.

When one compares the results of the path modeling with the results of the t-tests per measurement point, in COHORT 1, it showed that the t-tests of the achievement gap did not reach the adjusted p-level for multiple testing in both school subjects, but in the path model, ADHD was significant at T1 showing that it was a relevant predictor. There was more agreement between the t-tests of the group means and the path modeling In COHORT 2, as the achievement gap was significant at all three (language) and at two points of measurement (mathematics), as well as in the path model at T1 and T2.

Individual differences were important throughout the educational trajectories of COHORT 2. This may have been a result of the school closures during COVID-19. It could also have been the result of fewer pupils attending an academic school track than in COHORT 1. It is important to consider that in the path models, ADHD had to compete against other predictors that, even if not significant, would have shared variance. In the t-test comparisons of the group means of pupils with and without ADHD, this was not possible. Thus, also for future research on ADHD it is important to consider endogenous as well as exogenous variables.

Limitations

There are some limitations to the current study. There were differences between the cohorts in the way the school grades were reported, but in both cases, grades were reported in the school context where assessments took place. Another more self-imposed limitation was that we did not directly compare the two cohorts in our statistical analysis as we reckoned that the main difference between the two cohorts was the percentage of adolescents who were on the high school track (30.3% in COHORT 1 vs. 4.7% in COHORT 2). This would correspond to a higher socio-economic status of the parents that might have contributed to the smaller performance gap between pupils with and without ADHD as well as to fewer individual differences of COHORT 1 in the path models. Regrettably, we did not have information about the exact parental income in either project, only the duration of parental education as a proxy.

Moreover, another limitation is that we did not have information about the sub-type of ADHD, that is, whether inattention or hyperactivity was the more dominant symptom. Further research may investigate whether in school education, hyperactivity can be resolved by classroom rules and discipline, while inattention would be more likely to be resolved by captivating presentations and contextualization of content. We also did not have information whether the adolescents were on medication. These are data that were not addressed in the large educational longitudinal data sets because the data collection was planned with schools and teacher training in mind. Mental health and well-being in schools are officially in the focus of education politics, for instance, of the European Commission, only since a few years ago (Carta et al., 2015). Meta-analyses with comparisons of pharmacological and educational ADHD interventions are rare in Germany (Türk et al., 2023). However, physical exercise as in schools' sports education was shown to have a small but significant influence (Seiffer et al., 2022; Vysniauske et al., 2020). Already in preschoolers who are naturally motorically more agile, symptoms of hyperactivity and attention deficits could be ameliorated by different types of intervention, with personal scaffolding interventions being the most effective at this age (Pauli-Pott et al., 2021).

Conclusions

In conclusion, our investigation successfully analyzed school grades that were longitudinally assessed at three measurement points over three years of two relatively large samples of cohorts of pupils with and without ADHD, matching the samples on the variables age in months, sex, school type and dyslexia. The statistical results strongly suggest that in adolescence, schooling may help to reduce the association of ADHD symptoms with the core school grades of language and mathematics. As a valuable additional result for further research, the study showed that consideration of comorbidity of ADHD and dyslexia is essential to identifying an achievement gap in school grades making forecasts easier. In the smaller samples of pupils with both ADHD and dyslexia larger standard errors were found, so in the case of comorbidity, rather careful consideration of individual cases would be necessary. We could also find that there are competing factors that could diminish the association of ADHD with school grades such as parents' education and migration background towards the end of secondary education. These are not as easily ameliorated by pupils' self-efficacy as they are extraneous factors where the pupils themselves would have had no choice. Here, schools have an opportunity to provide accessible resources that are not available at home.

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Data availability The first draft of the article was written while the first author worked at the Leibniz Institute for Educational Trajectories. We analyze data from the projects 'National Educational Panel Study' (NEPS Network, 2024) (COHORT 1) and, Inclusion in and

after lower secondary tier in Germany‘ (INSIDE) (COHORT 2). Data collection of COHORT 1 is funded by the German Federal Ministry of Education and Research (BMBF) since 2014 https://www.lifbi.de/en-us/Start/Research/Large-Scale-Projects/COHORT1-National-Educational-Panel-Study/COHORT1-chronicles. A public user file is a vailable on https://www.neps-data.de/Data-Center/Data-Access. Data collection of COHORT 2 was also supported by the German Federal Ministry of Education and Research (BMBF) under grants IN1503A, IN1503B, IN1503C, and IN1503D to the Leibniz Institute for Educational Trajectories, Bamberg, Germany, in cooperation with a nationwide network. A public user data file will be published after project completion in 2025. The authors are solely responsible for the content of this study.

Declarations

Ethical standards Before data collection, permission was obtained from the government of each Bundesland. Permission was also obtained from each school.

Informed consent Informed consent was obtained from parents and adolescent participants. Withdrawal from the study could be sent via email at any time without disadvantage and the individual dataset would be deleted from each point of measurement.

Conflict of interest The authors report that there are no competing interests to declare.

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