

Childhood Behavior Problems and Academic Outcomes in Adolescence: Longitudinal Population-Based Study

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Objective: To investigate the impact of increasing levels of inattention, hyperactivity/impulsivity, and oppositional/defiant behaviors at age 7 years on academic achievement at age 16 years.

Method: In a population-based sample of 7-year-old children in England, information was obtained about inattention, hyperactivity/impulsivity, and oppositional/defiant behaviors (using parent and teacher ratings) and the presence of attention-deficit/hyperactivity disorder (ADHD) and disruptive behavior disorders (DBDs). After adjusting for confounder variables, their associations with academic achievement in national General Certificate of Secondary Education (GCSE) examinations (using scores and minimum expected school-leaving qualification level [5 "good" GCSEs]) at age 16 years were investigated (N = 11,640).

Results: In adjusted analyses, there was a linear association between each 1-point increase in inattention symptoms and worse outcomes (2- to 3-point reduction in GCSE scores and 6% to 7% (10%–12% with teacher ratings) increased likelihood of not achieving 5 good GCSEs).

ADHD was associated with a 27- to 32-point reduction in GCSE scores and, in boys, a more than 2-fold increased likelihood of not achieving 5 good GCSEs. In boys, oppositional/defiant behaviors were also independently associated with worse outcomes, and DBDs were associated with a 19-point reduction in GCSE scores and a 1.83-increased likelihood of not achieving 5 good GCSEs.

Conclusion: Across the full range of scores at a population level, each 1-point increase in inattention at age 7 years is associated with worse academic outcomes at age 16. The findings highlight long-term academic risk associated with ADHD, particularly inattentive symptoms. After adjusting for inattention and ADHD respectively, oppositional/defiant behaviors and DBDs are also independently associated with worse academic outcomes.

Key Words: inattention, oppositional/defiant, ADHD, academic outcomes, longitudinal

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Common behavioral disorders in childhood include attention-deficit/hyperactivity disorder (ADHD) and disruptive behavior disorders (DBDs).^{1,2} DBDs include oppositional defiant disorder (ODD), conduct disorder (CD), and disruptive behavior disorder not otherwise specified (DBD-NOS). Both ADHD and DBDs are associated with adverse outcomes including impaired peer and family relationships, reduced participation in developmentally appropriate activities inside and outside of school, substance misuse, criminality, impact on parental mental health, and costs to family and society.^{3–7} Furthermore, high levels of ADHD (including inattention and hyperactivity/impulsivity) and DBD (including oppositional/defiant and/or persistent rule-breaking behaviors) symptoms, even if subthreshold to reach full diagnostic criteria, are also risk factors for these outcomes.^{5,8,9}

Academic achievement at school-leaving age is an important factor influencing employment, occupational functioning, and socioeconomic status in adulthood. ADHD is associated with academic underachievement.^{10–13} By definition, the diagnostic criteria for ADHD include functional impairment, 1 domain of which reflects interference with academic functioning¹; hence ADHD (at diagnosis level) may be associated with academic outcomes because of impairment criteria. However, it is not clear whether increasing levels of ADHD symptoms carry risk only above a certain cut-off (threshold effect) or across the whole distribution of scores in the population. It is also not clear whether the long-term academic risk relates to both inattention and hyperactivity/impulsivity symptoms. Even if noticeable to parents or teachers, inattention symptoms may not be conceptualized by adults as problematic or a risk factor for later outcomes. Although inattentiveness is a stronger risk factor than hyperactivity/impulsivity symptoms for later academic difficulties,^{10,11,14–16} it has been suggested that hyperactivity might also have independent effects.¹⁷

Once ADHD symptoms are taken into account, there are also mixed findings about the independent effects of externalizing problems on later academic outcomes, with some studies finding little or no effect^{8,18,19} but others finding an association with oppositional/defiant and CD symptoms.^{20,21} This may reflect methodological differences,



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with larger studies generally being more likely to demonstrate an association. An exception is a study involving meta-analytic regression analyses of 6 longitudinal datasets (sample aged 4–6 years at baseline; $N > 34,000$).¹⁹ However, baseline externalizing problems were measured differently in each contributory dataset. In the study reporting an association with CD symptoms, the sample participants were older at baseline (age 4–18 years), which may have enabled an association to be detected.²¹

It has been recommended that longitudinal studies investigating the association between ADHD-type problems and academic outcomes account for key confounding factors including gender, IQ, socioeconomic status, and comorbidity.¹⁵ We aim to overcome some of the methodological limitations of previous studies by using prospective longitudinal data from a large community-based sample to account for these confounders and to minimize the impact of referral bias influencing the findings. In a previous analysis of a population-based cohort, we found that ADHD symptoms at age 3 years were associated with worse academic outcomes at age 16 years.²⁰ However, these analyses could not distinguish between inattention and hyperactivity/impulsivity symptoms. In the present study, we extend this work to a broader range of predictors reflecting both symptoms (inattention, hyperactivity/impulsivity, and oppositional/defiant) and disorders (ADHD and DBD), using information from both parents and teachers, assessed at the age of 7 years. Specifically, we aim to investigate which behaviors (inattention, hyperactivity/impulsivity, and oppositionality/defiance) at age 7 years are independently associated with adolescent academic outcomes, and the risk of long-term adverse academic outcomes associated with meeting criteria for ADHD or a DBD.

METHOD

Study Sample

Data are taken from the Avon Longitudinal Study of Parents and Children (ALSPAC), a prospective birth cohort study in England. Full details about the cohort design and recruitment are described elsewhere²² (www.bristol.ac.uk/alspac). In brief, pregnant women ($n = 14,541$) residing in the Avon area with an expected delivery date between April 1991 and December 1992 were recruited. Data have been collected at regular intervals through questionnaires completed by mothers and teachers, direct face-to-face assessments with study children, and linkage with specific external databases. The ALSPAC sample is representative of a mainly white population (5% of participants were from ethnic minority backgrounds) with diverse socioeconomic characteristics in keeping with the local population of mothers with infants and the United Kingdom overall. A total of 13,988 study children were alive at 1 year of age. The study website contains details of all the data that are available through a fully searchable data dictionary (<http://www.bris.ac.uk/alspac/researchers/data-access/data-dictionary/>). Ethical approval for the study was obtained from the ALSPAC Ethics and Law Committee and the local research ethics committees.

Matching of the ALSPAC database with the administrative National Pupil Database (NPD, the central repository in England for pupil-level educational data) provided details of the children's results in the General Certificate of Secondary Education (GCSE)

examinations at age 16 years. Information about GCSE results (main outcome measure) were available for all pupils attending publicly funded state schools in England. In total, GCSE attainment data were available for 11,640 children (83% of the core ALSPAC sample). Further details of these examinations are given below.

Measures

Predictor Variables. Parents (either mother or father) and teachers completed the Development and Well-Being Assessment (DAWBA)²³ when the child was aged 7 years (~91 months of age). This reliable and well-validated measure consists of a structured combined package of parent and teacher questionnaires, and incorporates open questions allowing free-text answers. The DAWBA has been used in other large epidemiological studies, including the 2 nationally representative British Child and Adolescent Mental Health Surveys.^{2,24} For this study, the key variables of interest relate to inattention, hyperactivity/impulsivity, and oppositional/defiant behaviors. The DAWBA questions relate closely to *DSM-IV* items and focus on current problems and associated impairment. Response rates were 59% for parent-completed and 47% for teacher-completed DAWBAs.

From the DAWBA, the following information was used. For symptoms, each item was scored from 0 to 2 reflecting the level of severity. Parents were asked about behavior in the last 6 months and in relation to that of other children (scored 0 for “no more than others”; 1 for “a little more than others”; 2 for “a lot more than others”). Teachers were asked about behavior over the last school year (scored 0 for “not true”; 1 for “somewhat true”; 2 for “certainly true”). Each domain listed had 9 items with a total score range of 0 to 18 (except the teacher-completed inattention scale involving 10 items and score range of 0–20): inattention, hyperactivity/impulsivity, and oppositional/defiant behaviors. For diagnoses, experienced clinicians reviewed all available symptom and impairment information from the parent- and/or teacher-completed DAWBAs ($n = 7,084$) in assigning *DSM-IV* diagnoses.²⁵ The following diagnoses were used in analyses: ADHD (any subtype: inattentive, hyperactive/impulsive, combined); and DBDs, including ODD, CD, and DBD-NOS (at this age, most children with a DBD met criteria for ODD).

Academic Outcome Variables. These are the nationally graded GCSE examinations. They are taken during the academic year in which pupils reach the age of 16 years; class repetition is not a feature of the English educational system. GCSE examinations are externally marked, providing an objective “real-world” measure of academic attainment. In England, these are crucial examinations that assess academic performance at the end of compulsory schooling and determine transition into post-compulsory education and likelihood of employment for those leaving school. For GCSE, pupils study up to 12 subjects (8 on average) of which some (e.g., English and mathematics) are compulsory. Grades range from A* (highest) to G (lowest), and universities and employers consider A* to C as passing grades.

The following information was used for analyses. First, continuous scores were used to assess effects across the full distribution of pupil ability, based on the summed total of points from the best 8 GCSE grades achieved. This scoring reflects a minimum of 16 points for a G grade with an additional 6 points per each grade increase, leading to a maximum of 58 points for an A* grade.²⁶ The use of a capped (best 8) total point score minimizes the likelihood of the number of GCSEs taken and awarded grades being conflated. Normative national data for the study years indicate that mean scores ranged between 295 and 318 points, compared with 316 in ALSPAC. Second, a binary outcome (yes/no) was used to assess

TABLE 1 Descriptive Statistics

	Whole Sample % or Mean (SD) N = 11,640	Boys % or Mean (SD) n = 5,917	Girls % or Mean (SD) n = 5,723	Gender Difference p Values
Female, %	49	—	—	—
Capped GCSE points ^a	315.82 (96.20)	303.87 (99.3)	328.18 (91.3)	<.001
Failed to get 5 A*-C GCSE's ^b , %	49	54	44	<.001
Parent-rated inattention (0–18)	2.84 (3.69)	3.37 (4.02)	2.29 (3.23)	<.001
Parent-rated hyperactivity/impulsivity (0–18)	2.75 (3.55)	3.19 (3.88)	2.30 (3.11)	<.001
Parent-rated oppositional/defiant behavior (0–18)	1.71 (2.89)	1.87 (3.04)	1.54 (2.72)	.002
Teacher-rated inattention (0–20)	4.82 (5.11)	6.21 (5.50)	3.38 (4.22)	<.001
Teacher-rated hyperactivity/impulsivity (0–18)	1.84 (3.38)	2.80 (3.99)	0.85 (2.18)	<.001
Teacher-rated oppositional/defiant behavior (0–18)	1.54 (3.00)	2.15 (3.47)	0.91 (2.25)	<.001
ADHD, %	4.0	5.2	2.6	<.001
DBD, %	6.6	8.1	5.1	.001
Mother's highest qualification, %				
CSE/none	23	23	23	.722
Vocational	11	11	11	.908
O-level	35	35	36	.780
A-level	21	21	21	.807
Degree	10	10	10	.605
Father's highest qualification, %				
CSE/none	28	28	28	.869
Vocational	10	10	9	.404
O-level	22	23	22	.871
A-level	26	25	27	.076
Degree	14	15	14	.138
Social class (highest of either parent), %				
Professional	11	11	10	.204
Managerial/technical	38	39	38	.518
Skilled nonmanual	29	29	28	.324
Skilled manual	15	14	15	.364
Semi-skilled	6	5	7	.001
Unskilled	2	2	2	.983
WISC IQ at 8 years	99.6 (17.8)	99.6 (18.4)	99.6 (17.1)	.973
Average maternal EPDS ^c	6.24 (3.81)	6.22 (3.84)	6.26 (3.78)	.671

Note: Means and standard deviations calculated over 5 complete imputed datasets and combined using Rubin's rules. ADHD = attention-deficit/hyperactivity disorder; CSE = Certificate of Secondary Education; DBD = disruptive behavior disorder; EPDS = Edinburgh Postnatal Depression Scale; GCSE = General Certificate of Secondary Education; WISC = Wechsler Intelligence Scale for Children.

^aCapped GCSE points are the sum over the 8 best GCSE grades, scored 6 points per each grade increase (from G = 16 to A* = 58).

^bIncluding English and mathematics.

^cAverage of scores at 18 and 32 weeks gestation (pregnancy), and 8 weeks and 8, 21, and 33 months postbirth.

whether minimum expected criteria were achieved (i.e., at least 5 A*-C grade GCSEs, including English and mathematics). This minimum level (5 "good" GCSEs) is important, as it is a requirement for progression into post-compulsory education and is a key performance indicator for schools in England that is published in league tables of school comparisons. Data for the study years indicate that 46% to 50% of children in England achieved 5 "good" GCSEs, compared with 51% in ALSPAC.

Confounder Variables. The analyses adjusted for a range of factors that might confound the association between inattention, hyperactivity/impulsivity, or oppositional/defiant behavior problems and academic attainment. Child factors comprised IQ score assessed at age 8 years using the Wechsler Intelligence Scale for Children-III (WISC-III²⁷). Parent factors included parental socio-demographic measures that were collected from self-completed questionnaires during the pregnancy. These included the following: the highest

social class of either parent (based on the Registrar General's classification of occupations into 6 categories: I [professional], II [managerial and technical], IIIa [skilled manual], IIIb [skilled nonmanual], IV [semi-skilled], and V [unskilled]).²⁸ In addition, the highest level of maternal and paternal academic attainment was ascertained (using 5 categories: Certificate of Secondary Education [CSE] or less, vocational qualification, "O" level [the predecessor to the GCSE], "A" level or equivalent [examinations taken at age 18 years after 2 years of postcompulsory education], and university degree or equivalent). As the parent DAWBA was usually completed by the mother, measures assessing maternal mental health available in ALSPAC were used. The well-validated Edinburgh Postnatal Depression Scale (EPDS)^{29,30} was completed by mothers at 18 and 32 weeks gestation and at 8 weeks and 8, 21, and 33 months postbirth. As a measure of maternal depression, the average of these EPDS scores was used in the analyses.

TABLE 2 Regression Analyses of Relationships Between Capped General Certificate of Secondary Education Points and Inattention, Hyperactivity/Impulsivity, and Oppositional/Defiant Behaviors, Along With Diagnoses

	Boys n = 5,917			Girls n = 5,723		
	Unadjusted Coefficients (SE)	Partially Adjusted Coefficients (SE) ^a	Fully Adjusted Coefficients (SE) ^b	Unadjusted Coefficients (SE)	Partially Adjusted Coefficients (SE) ^a	Fully Adjusted Coefficients (SE) ^b
Symptoms						
Inattention	-7.31** (0.36)	-5.49** (0.49)	-2.28** (0.36)	-7.70** (0.44)	-5.63** (0.62)	-2.33** (0.45)
Hyperactivity/impulsivity	-6.46** (0.41)	-1.65* (0.67)	-1.56** (0.48)	-7.06** (0.56)	-2.54** (0.76)	-0.74 (0.54)
Oppositional/defiant	-6.60** (0.62)	-1.97** (0.74)	-1.42* (0.64)	-5.42** (0.61)	-1.07 (0.63)	-0.87 (0.73)
R ²		0.094	0.478		0.076	0.451
Diagnoses						
ADHD	—	-58.47** (11.48)	-32.31** (9.38)	—	-77.48** (18.58)	-27.64** (12.52)
DBD	—	-45.31** (8.23)	-18.85** (5.50)	—	-40.25** (8.94)	-16.76 (10.05)
R ²		0.032	0.460		0.018	0.443

Note: Combined estimates from 5 multiply imputed datasets. ADHD = attention-deficit/hyperactivity disorder; DBD = disruptive behavior disorder; SE = standard error.
^aMutually adjusted for inattention, hyperactivity/impulsivity, and oppositional/defiant behaviors, and for corresponding diagnosis and interaction.
^bAdditionally adjusted for child IQ, parental education and social class, and early maternal depression.
p* < .05; *p* < .01.

Statistical Analysis

ALSPAC, like many long-term longitudinal cohort studies, is affected by attrition and item nonresponse. Our primary measures of behavior are observed for 59% of the sample, with response rates for other covariates ranging between 53% (IQ) and 93% (maternal education). Use of complete cases only, however, reduces the analysis sample to 32% of its original size (3,680 of 11,640 children), resulting in considerable loss of valid data and, more importantly, a high risk of bias in the estimates. Complete case analysis results in bias if outcomes associated with a given set of covariate values differ systematically between observed and missing cases.³¹ In this application, bias will arise if, for example, children with behavioral problems who remained in the study tended to have better educational outcomes than children with identical observed characteristics whose parents did not complete all relevant questionnaires. It seems probable that there are many factors that, by affecting family life, could both reduce participation over each wave of data collection in ALSPAC and hamper children's educational attainment, and thus violate the assumptions required for valid complete case analysis. Unusually in the presence of missing data, our outcome variables are fully observed because they are taken from administrative data. This shows, for example, that the average GCSE score is 55 points lower (>0.5 SD) in the sample with missing covariate data compared to the complete case sample. This provides additional justification for concerns that covariate missingness and educational outcomes are negatively related.

We provide complete case estimates of all models (see Supplement 1, available online) but caution that these results may be unreliable because of the strongly selected nature of the sample. In line with previous work using ALSPAC,³² our primary results use multiple imputation by chained equations to deal directly with the problems arising from missing data and to fully exploit the information contained in our sample (e.g., by including 3,171 participants for whom the DAWBA and the outcome are fully observed but at least 1 covariate is missing).³³ In addition to the primary variables used in the principal analyses, we used 78 auxiliary variables taken from the ALSPAC dataset in the imputation. These included all of the subscale scores from the Strengths and Difficulties Questionnaire (SDQ),³⁴ a well-validated measure of childhood mental health, which was obtained on 8 separate

occasions from either the parent or teacher between the ages of 3 and 13 years; receipt of free school meals and special educational needs status; academic achievement outcomes from Key Stage national tests taken at ages 7, 11, and 14 years; birth weight; and mother's age. By including this wide range of additional variables, missing data on behavior problems and other covariates can be predicted with considerable accuracy, and children with valid behavior scores and outcomes who have missing data on other covariates can be included in the analysis. We ran 5 multiple imputations, separately for girls and boys, using the Stata command *ice*. Estimates were combined by using Rubin's rules through the command *mim*.³⁵ Further details on multiple imputation and its application are provided in Supplement 1, available online.

The analyses involved the 6 stages described below.

In stage 1, gender-specific (as there are gender differences in behavior problems and GCSE outcomes [Table 1]) multivariable linear regression analyses were used to examine the effect of each 1-point increase in symptoms on capped GCSE points after adjusting for confounder variables. The main analytic model used parent-completed DAWBA scores because, compared to teacher ratings, these may be less biased by the child's academic progress. Analyses were repeated using teacher-completed DAWBA scores to assess whether key findings were replicated (confirmatory model). These linear regression analyses inform about any gradient effects of increasing levels of inattention, hyperactivity/impulsivity, and oppositional/defiant behavior problems on outcomes. The predictor and confounder variables were introduced sequentially over 2 steps: step 1, mutually adjusting for inattention, hyperactivity/impulsivity, and oppositional/defiant behavior problems; and step 2, also adjusting for child IQ, parental socio-demographic factors (highest social class of either parent, highest level of maternal education, and highest level of paternal education), and maternal depression.

In stage 2, the analyses in stage 1 were repeated to assess the impact on academic outcomes of having a diagnosis of ADHD and/or DBD. Diagnosis information (instead of symptoms) was used as the key predictor variable. Assessments were also made for interactions between ADHD and DBD.

In stage 3, gender-specific multivariable logistic regression analyses were carried out to assess the impact of 1-point increases in inattention, hyperactivity/impulsivity, and oppositional/defiant

behavior scores (using the parent-completed DAWBA) on the achievement of 5 A* to C grades. These analyses inform about the extent to which increasing levels of different types of symptoms predict failure to achieve minimum expected qualifications. As in stage 1, predictor and confounder variables were introduced into a multivariable logistic regression model over 2 steps to provide adjusted odds ratio estimates.

In stage 4, the analyses in stage 3 were repeated to assess the impact of having a diagnosis of ADHD and DBD on achieving minimum expected qualifications, using these instead of symptoms as the key predictor variables. Assessments were also made for interactions between ADHD and DBD.

In stage 5, stages 1 and 3 were repeated in a confirmatory model using the teacher-completed DAWBA instead of the parent-completed DAWBA as the predictor measure.

Finally, in stage 6, sensitivity analyses for stages 1 to 4 were carried out to provide estimates for participants who had complete data (complete case analyses).

To assess whether the increases in DAWBA scores, after all adjustments, had linear or nonlinear effects, quadratic (squared) terms of each DAWBA subscale were added to the models in stages 1 and 3. The quadratic terms were not statistically significant in any of the models. We also used higher-order polynomials and explored the possibility of threshold effects at points suggested by graphical analysis but found no evidence in any model of a nonlinear relationship between any behavior score and the academic outcome.

RESULTS

Descriptive statistics (Table 1) show that boys had higher levels of behavior problems and rates of disorder, achieved fewer GCSE points, and were less likely to obtain the minimum expected 5 A* to C grades.

Relationships Among Inattention, Hyperactivity/Impulsivity, and Oppositional/Defiant Behavior Problem Scores and Diagnoses and GCSE Points

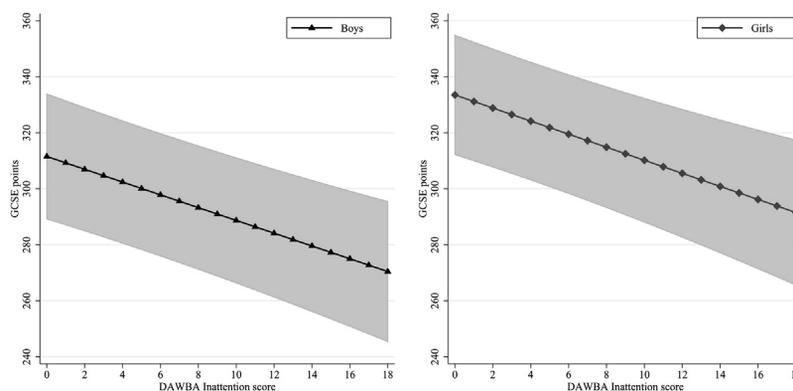
Table 2 shows the regression coefficients for inattention, hyperactivity/impulsivity, and oppositional/defiant symptoms

with different levels of adjustments to the model. The unconditional model (first column) shows that boys achieved 6 to 7 fewer points (equivalent to 1 GCSE grade) per each 1-point increase in inattention, hyperactivity/impulsivity, and oppositional/defiant symptoms. Mutual adjustment reduced these coefficients to 5, 2, and 2 points, respectively (column 2), suggesting confounding. The coefficient for inattention was reduced further after adjusting for IQ, parental socio-demographic factors, and maternal depression (column 3). In fully adjusted models, these estimates suggest a 1- to 2-point penalty in total GCSE points per each 1-point increase in each type of symptom. When considered diagnostically, both ADHD and DBDs exerted independent effects (yielding effect sizes of -0.33 and -0.19 respectively) that were additive, with no evidence of interaction effects. Among girls, the adjusted analyses also found evidence for effects of similar magnitude in relation to each 1-point increase in inattention and ADHD (effect size -0.30) but no significant effect for the other behavior problems or DBDs.

In each model, the effects of increases in DAWBA scores were linear: there was no evidence that the effect of a 1-point increase varied depending on the initial level of the score. Figure 1 shows the predicted relationships between the DAWBA inattention scores and GCSE outcomes implied by the linear models with all controls. Each plot holds constant all other covariates at their mean values (different for boys and girls).

The confirmatory model involving the teacher-completed DAWBA also found a 2- to 3-point penalty related to inattention symptoms (in both genders) and a 1- to 2-point penalty related to hyperactivity/impulsivity (in boys). As shown in Table S1 (available online), sensitivity analyses involving fully adjusted models from the complete case analyses confirmed a 2- to 3-point penalty related to inattention symptoms in both genders.

FIGURE 1 Predicted relationship between parent-completed Development and Well-Being Assessment (DAWBA) Inattention score at age 7 years and educational achievement at the end of compulsory schooling (age 16 years).^a Note: $n = 5,917$ boys and $5,723$ girls. GCSE = General Certificate of Secondary Education. ^aPredictions derived from a linear regression model with multiple imputation. Control variables are DAWBA hyperactivity/impulsivity and oppositional/defiant behavior scores at age 7 years; parental education and social class, child IQ at age 8 years, and early maternal depression. Control variables are set at their mean values for the purpose of prediction.



Relationships Among Inattention, Hyperactivity/Impulsivity, and Oppositional/Defiant Behavior Problem Scores and Diagnoses and Achievement of 5 A* to C Grades

Logistic regression analyses (Table 3) showed that, after adjusting for child IQ, maternal and paternal education, parental social class, and maternal depression, each 1-point increase in inattention in both boys and girls was associated with failure to achieve 5 good GCSEs. These estimates suggest a 6% to 7% increased risk per each 1-point increase in inattention symptoms. As shown in Figure 2, these effects were linear. In boys, when considered diagnostically, both ADHD and DBDs exerted independent effects that were additive, with no evidence of interaction effects.

The effects for inattention were of greater magnitude (10% increased risk in boys and 12% in girls in adjusted analyses) in the confirmatory model involving the teacher-completed DAWBA. As shown in Table S2 (available online), sensitivity analyses involving fully adjusted models from the complete case analyses found similar associations relating to inattention symptoms (in both genders).

DISCUSSION

This large, 9-year follow-up study highlights the adverse effects of early childhood behavioral difficulties on educational outcomes in adolescence. The findings were robust to a range of analyses that used parent or teacher ratings as predictor variables and dimensional (symptom scores) or categorical (diagnosis) measures as outcome variables. The findings confirm that inattention, particularly if noticeable to a parent or teacher, is a stronger predictor than hyperactivity/impulsivity of later academic difficulties.^{10,11,14-16} However, in boys, we also found that hyperactivity/impulsivity symptoms carried an independent risk. The magnitude of the increased risk was constant per each 1-point increase across the whole score range of each behavior symptom. This suggests that, rather than there being threshold effects whereby children above a certain cut-off have worse outcomes (with each 1-point increase), there are gradient effects across the whole population of increasing symptoms on academic outcomes.

As well as confirming the association between ADHD and worse academic outcomes,¹⁰⁻¹³ the findings also highlight the independent risk, in boys, associated with oppositional/defiant symptoms and meeting criteria for DBDs. Although some studies have not found an independent effect of these externalizing problems,^{8,18,19} more recent, large-scale studies highlight their association with poor academic outcomes.^{20,21}

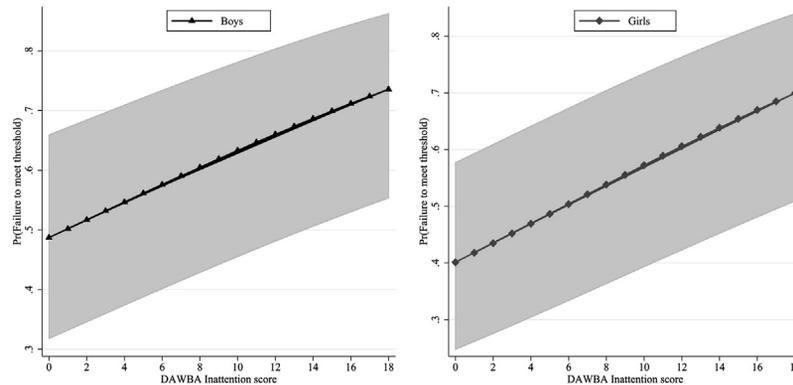
This study has a number of strengths. First, the large sample size permitted gender-specific analyses, which are important, as childhood behavioral problems and adolescent academic attainment vary by gender. Second, we were able to distinguish between the risk associated with inattention and hyperactivity/impulsivity symptoms and to assess the independent effects of oppositional/defiant

TABLE 3 Adjusted Odds Ratios (OR) of Predictors of Failure to Achieve 5 Good General Certificates of Secondary Education

Predictor	Boys			Girls		
	Unadjusted OR (95% CI)	Partially Adjusted OR (95% CI) ^a	Fully Adjusted OR (95% CI) ^b	Unadjusted OR (95% CI)	Partially Adjusted OR (95% CI) ^a	Fully Adjusted OR (95% CI) ^b
Symptoms						
Inattention	1.13 (1.12, 1.15)**	1.10 (1.08, 1.13)**	1.06 (1.03, 1.10)**	1.17 (1.13, 1.20)**	1.12 (1.07, 1.18)**	1.07 (1.02, 1.13)**
Hyperactivity/impulsivity	1.11 (1.09, 1.13)**	1.03 (0.99, 1.06)	1.03 (0.99, 1.07)	1.15 (1.12, 1.17)**	1.05 (1.01, 1.09)*	1.02 (0.99, 1.06)
Oppositional/defiant	1.11 (1.07, 1.14)**	1.03 (0.99, 1.06)	1.02 (0.98, 1.06)	1.11 (1.08, 1.14)**	1.02 (0.98, 1.05)	1.02 (0.97, 1.07)
Diagnoses						
ADHD	—	2.64 (1.57, 4.43)**	2.11 (1.05, 4.21)*	—	3.84 (2.13, 6.93)**	1.80 (0.96, 3.39)
DBD	—	2.38 (1.62, 3.49)**	1.83 (1.22, 2.76)**	—	2.29 (1.56, 3.36)**	1.77 (0.88, 3.55)

Note: Combined estimates from 5 multiply imputed datasets. ADHD = attention-deficit/hyperactivity disorder; DBD = disruptive behavior disorder.
^aMutually adjusted for inattention, hyperactivity/impulsivity, and oppositional/defiant behaviors, and for corresponding diagnosis and interaction.
^bAdditionally adjusted for child IQ, parental education and social class, and early maternal depression.
 *p < .05; **p < .01.

FIGURE 2 Predicted relationship between parent-completed Development and Well-Being Assessment (DAWBA) Inattention score and failure to achieve at the expected educational threshold at the end of compulsory schooling (age 16 years).^a Note: $n = 5,917$ boys and 5,723 girls. Pr = probability. ^aThe expected threshold is 5 A* to C General Certificates of Secondary Education (GCSEs) including English and mathematics. Predictions derived from a logistic regression model with multiple imputation. Control variables are DAWBA hyperactivity/impulsivity and oppositional/defiant behavior scores at age 7 years; parental education and social class, child IQ at age 8 years, and early maternal depression. Control variables are set at their mean values for the purposes of prediction.



symptoms. Third, our analyses enabled us to focus on the full spectrum of these behaviors (dimensional approach) as well as on those individuals at the extreme end who met disorder criteria (categorical approach). Fourth, our analyses adjusted for key confounder variables, including child IQ as well as parental education and socio-economic status. Fifth, we used an externally marked measure of academic outcome. For the key predictor variable, we were able to use parent ratings. Compared to teacher ratings, these are less likely to be biased by children's academic progress and achievements. However, we also carried out confirmatory analysis using teacher ratings, and the pattern of findings was similar. Sixth, the use of a community-based sample meant that the findings related to ADHD and DBDs were not influenced by referral bias. The findings reflecting diagnostic-level variables quantified the magnitude of educational disadvantage associated with ADHD or DBDs, of which clinicians and educators should be aware.

The study also has several methodological limitations. First, there was considerable sample attrition over the follow-up period. However, variables in the ALSPAC dataset informed about the extent of selection bias, and previous work in ALSPAC has demonstrated that selective drop-out does not bias prediction of risk of behavioral disorders.²⁵ Furthermore, estimates from multiple imputation and complete case analyses were broadly comparable (although, as expected, the latter reflected wider confidence intervals). The key findings involving negative effects of inattention symptoms in the fully controlled model for both genders, and both types of outcome, were robust to limiting the sample to complete cases. Second, no information was available on school factors (such as school prioritization of academic results and standard of teaching) or intervening factors such as receipt of a clinical diagnosis or medication. However, during the study period, relatively few children in Britain with ADHD received a clinical referral or medication for this.³⁶ Medication may also

have limited effect on longer-term academic achievement.³⁷ Third, children with behavioral difficulties may have impairments in executive functioning (reflecting working memory and response inhibition), which might contribute to their academic difficulties. However, we were unable to assess for these.

In terms of possible mechanisms, there may be direct effects whereby, compared to hyperactivity/impulsivity symptoms, inattention may be more likely to persist into teenage years, when crucial school examinations are taken. Inattention may also affect the development of academic skills in the early school years and may have an impact on engagement and participation in the classroom, homework completion, motivation, and organization and planning skills. During adolescence, these difficulties may be exacerbated by the increase in academic demands and requirement for sustained attention. Other indirect effects might reflect associations with specific learning or executive functioning difficulties.^{38,39} Brain correlates of ADHD include smaller brain volume and cortical thinning,^{40,41} and executive function deficits may interact with ADHD in predicting worse academic outcomes.³⁹

In terms of implications, teachers and parents should be aware of the academic impact of early behavioral difficulties, and, in particular, the risk associated with sub-threshold difficulties. Increasing levels of behavioral problems at age 7 are associated with worse academic outcomes in adolescence. Although each 1-point increase in inattention symptoms has a small effect at an individual level, the impact is significant at a population level. This demonstration of a dose-response relationship has important clinical and educational implications; diagnostic systems that are based on having a minimum number of definite symptoms or symptoms of sufficient severity mean that children who are subthreshold for ADHD may be overlooked. Our findings highlight that prevention and intervention approaches, including educational support, should consider the full spectrum of these behavioral risk

factors and not just focus on those with extreme levels of difficulties. Interventions for academic difficulties should take into account the presence of inattention and DBD symptoms, and strategies should be tailored accordingly. At the individual level, strategies that might help to optimize examination performance during teenage years include time management and organization skills (throughout the course of study), prioritization of key work, minimizing distractions, examination revision, and within-examination strategy.



Clinical Guidance

- At a population level, after adjusting for a range of confounder variables, there is a linear association between each 1-point increase in inattention symptoms at age 7 years and worse academic outcomes at age 16 years. Our outcome measure (GCSE examination results) reflects high-stakes examinations that determine future education trajectory and employment opportunities.
- As increasing levels of inattention symptoms heighten the risk of worse academic outcomes across the whole range of scores in the population (not just above a certain cut-off), this has important clinical and educational implications.
- Among boys, oppositional/defiant behaviors are independently associated with worse academic outcomes. In particular, after adjusting for the presence of ADHD, DBDs exerted an additive independent effect on adverse outcomes.
- Diagnostic systems that are based on requiring a minimum number of definite or severe symptoms might mean that the educational needs of children who are subthreshold for ADHD or DBDs are overlooked.

Clinicians and teachers should also be aware of the independent risk associated with oppositional-defiant behaviors and DBDs, especially in boys. Community-based interventions such as parenting programs are effective in reducing behavior problems in at-risk children.⁴² The addition of educational interventions such as literacy programs can improve reading ability.⁴² There is a need for future research to investigate whether parent-based behavioral interventions and educational interventions for children with behavioral problems have an impact on academic achievement. &

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SUPPLEMENT 1: MULTIPLE IMPUTATION BY CHAINED EQUATIONS

In brief, the method of multiple imputation (MI) uses the distribution of the observed data to estimate a set of plausible values for the missing data. Multiple datasets are created, each of which contains different imputed values of the missing data. The datasets are then analyzed individually but identically to obtain a set of parameter estimates, which are then combined in the final step to obtain the overall estimates, variances, and confidence intervals. A common misconception is that MI simply “fills in” missing values and then proceeds as if the dataset were fully observed. Crucially, however, uncertainty about the values of the missing data is preserved by random variation in these values across the multiple imputed datasets, and is thus incorporated into the final estimates and their confidence intervals. Theoretically, there is no lower bound to the response rate needed to apply multiple imputation. However, large fractions of missing data will tend to produce imputed values that vary widely across datasets, resulting in imprecise estimates in the final analysis model. Rubin and Schenker¹ provide an example in which just 3 imputations produce accurate results for a sample with only a 40% response rate. We use 5 imputations in our analysis and do not impute for any variable with a response rate of less than 53%.

There are several methods that can be used to calculate the plausible values of the missing data. Our approach is to use chained equations, in which every variable in the dataset but 1 is used in a predication equation for the excluded variable.² Intermediate missing values of the dependent variable are calculated as draws from the predictive distribution implied by the equation, and the process cycles multiple times (10 in our application) through each variable in turn, refining the predictive distribution each time. This process results in a single imputed dataset: 5 separate runs through the cycling process are required to produce the 5 imputed datasets for analysis. Imputation was conducted separately for girls and boys, using the Stata command *ice*, and the 5 sets of estimates were combined using the command *mim*.³

Inclusion of Auxiliary Variables

As noted, wide variation in the imputed values across datasets will result in imprecise estimates in the final analysis model. In addition, the imputation model must account for all systematic sources of variation in the variables to be

imputed: values must be missing at random (MAR) conditional on the variables contained in the imputation model, or the final estimates will be biased. For both of these reasons, there are benefits to specifying a “richer” imputation model that includes more predictors than the final analysis model of interest.⁴ If the additional auxiliary variables are predictors of the incomplete variables and of whether the incomplete variables are missing, their inclusion helps to satisfy the MAR assumption and improves the accuracy of the imputed values. Set against this, there is some concern that the inclusion of irrelevant auxiliary variables can lead to a loss of precision in estimation of the analysis model. Our auxiliary variables are carefully selected because of their likely correlation with the analysis variables. However, to the extent that any of them are unnecessary, loss of precision would tend to bias us away from finding significant effects. The consensus in the literature is that auxiliary variables can be of great benefit. As Carpenter and Kenward⁴ argue, “when building an imputation model it is better to err on the side of over-fitting rather than under-fitting. We see that the penalty for over-fitting, i.e. having a richer imputation model than strictly necessary, is some conservatism, probably slight, while omitting key variables can lead to inconsistent estimators” (p. 69). They go on to quote studies by Rubin⁵ and Collins *et al.*⁶ in support of the contention that “the inclusive strategy is much to be preferred.”

In the Avon Longitudinal Study of Parents and Children (ALSPAC), we are fortunate to have a wide variety of auxiliary variables available that are strongly correlated with the key analysis measures, including varied measures of behavior and achievement at multiple points over the course of childhood. In total, 78 auxiliary variables were used to supplement the imputation model. With regard to correlates of behavior, we included all of the subscale scores from the Strengths and Difficulties Questionnaire (SDQ)⁷, a well-validated measure of childhood mental health, which was obtained on 8 separate occasions from either the parent or teacher between the ages of 3 and 13 years (40 variables in total). More than 90% of the sample have at least 1 SDQ observation, and the close conceptual relationship between these variables and the DAWBA should greatly improve the accuracy of the imputed values of the latter. We also include an indicator of special educational needs, which comes from the administrative education dataset and is observed for 98% of cases. Other included variables with very high response rates included academic achievement outcomes from Key Stage national tests taken at ages 7, 11, and 14 years, receipt of free school meals, birth weight, and mother’s age.

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TABLE S1 Regression Analyses of Relationships Between Capped General Certificate of Secondary Education (GCSE) Points and Inattention, Hyperactivity/Impulsivity, and Oppositional/Defiant Behaviors, Along With Diagnoses: Complete Case Samples

	Boys n = 1,811			Girls n = 1,869		
	Unadjusted Coefficients (SE)	Partially Adjusted Coefficients (SE) ^a	Fully Adjusted Coefficients (SE) ^b	Unadjusted Coefficients (SE)	Partially Adjusted Coefficients (SE) ^a	Fully Adjusted Coefficients (SE) ^b
Symptoms						
Inattention	-6.24** (0.44)	-5.42** (0.62)	-3.08** (0.51)	-5.91** (0.51)	-4.31** (0.71)	-2.26** (0.57)
Hyperactivity/impulsivity	-5.07** (0.45)	-1.08 (0.68)	-0.68 (0.55)	-5.52** (0.53)	-2.19** (0.79)	-1.04 (0.63)
Oppositional/defiant	-4.68** (0.64)	-0.20 (0.76)	-1.10 (0.61)	-3.94** (0.64)	-0.29 (0.73)	-0.61 (0.58)
R ²	—	0.103	0.432	—	0.073	0.431
Diagnoses						
ADHD	—	-83.30** (12.97)	-69.94** (10.21)	—	-129.29** (22.69)	-80.12** (17.71)
DBD	—	-24.68* (11.31)	-8.56 (8.93)	—	-18.57 (12.71)	-6.44 (9.83)
R ²	—	0.041	0.419	—	0.031	0.431

Note: ADHD = attention-deficit/hyperactivity disorder; DBD = disruptive behavior disorder; SE = standard error.
^aMutually adjusted for inattention, hyperactivity/impulsivity, and oppositional/defiant behaviors, and for corresponding diagnosis.
^bAdditionally adjusted for child IQ, parental education and social class, and early maternal depression.
 *p < .05; **p < .01.

TABLE S2 Adjusted Odds Ratios (OR) of Predictors of Failure to Achieve 5 Good General Certificates of Secondary Education: Complete Case Samples

Predictor	Boys			Girls		
	Unadjusted OR (95% CI)	Partially Adjusted OR (95% CI) ^a	Fully Adjusted OR (95% CI) ^b	Unadjusted OR (95% CI)	Partially Adjusted OR (95% CI) ^a	Fully Adjusted OR (95% CI) ^b
Symptoms						
Inattention	1.14 (1.11, 1.17)**	1.11 (1.07, 1.15)**	1.08 (1.03, 1.12)**	1.15 (1.11, 1.19)**	1.11 (1.07, 1.17)**	1.07 (1.02, 1.13)**
Hyperactivity/impulsivity	1.11 (1.09, 1.14)**	1.04 (1.00, 1.08)	1.04 (1.00, 1.09)	1.13 (1.10, 1.17)**	1.04 (0.99, 1.09)	1.02 (0.96, 1.08)
Oppositional/defiant	1.09 (1.05, 1.13)**	0.99 (0.95, 1.03)	1.01 (0.96, 1.06)	1.10 (1.06, 1.15)**	1.02 (0.97, 1.07)	1.03 (0.98, 1.09)
Diagnoses						
ADHD	—	5.60 (2.52, 12.45)**	6.83 (2.68, 17.43)**	—	22.01 (2.75, 176.45)**	16.25 (1.66, 159.02)*
DBD	—	1.65 (0.91, 2.98)	1.34 (0.69, 2.58)	—	1.94 (0.92, 4.10)	1.84 (0.76, 4.42)

Note: ADHD = attention-deficit/hyperactivity disorder; DBD = disruptive behavior disorder.
^aMutually adjusted for inattention, hyperactivity/impulsivity, and oppositional/defiant behaviors, and corresponding diagnosis and interaction.
^bAdditionally adjusted for child IQ, parental education and social class, and early maternal depression.
 *p < .05; **p < .01.