Acta Psychiatr Scand 2010: 122: 271–284

DOI: 10.1111/j.1600-0447.2010.01568.x

ACTA PSYCHIATRICA SCANDINAVICA

Review

A systematic review of prospective studies on attention problems and academic achievement

Polderman TJC, Boomsma DI, Bartels M, Verhulst FC, Huizink AC. A systematic review of prospective studies on attention problems and academic achievement.

Objective: Our aim was to provide an overview of prospective studies that have addressed the association between attention problems (AP, i.e. symptoms of hyperactivity and inattentiveness) and academic achievement (AA).
Method: We conducted a systematic search in the literature. Normal population studies and clinical studies were included. The methodological quality of each study was evaluated by objective criteria. A best evidence synthesis was used to determine the strengths of the association.
Results: Sixteen studies were included. We found convincing evidence for a negative association between AP and AA. After controlling for intelligence, comorbidity, and socioeconomic status (SES), the association between the hyperactive symptoms of AP and AA was non-significant in two studies.
Conclusion: Children with AP are at risk for lower AA and subsequent adverse outcomes later in life. Interventions in affected children should focus on their behavioural and educational development.

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Key words: attention deficit disorder with hyperactivity; educational status; child; longitudinal studies

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Accepted for publication March 30, 2010

Summations

- Attention problems (i.e. symptoms of hyperactivity and inattentiveness) predict academic problems, varying from grade repetition and need for special education, to lower scores on achievement tests.
- After correcting for IQ, SES and comorbid disorders, especially the negative relation between inattentiveness and AA is strong.
- Low AA is a salient adverse outcome; behavioural as well as cognitive (teacher mediated) interventions are advisable in affected children.

Considerations

- Prospective studies on the relation between AP and AA are relatively limited and study characteristics vary considerably. However, the direction of the effect is largely the same in all studies.
- The association between AP and covarying factors (i.e. comorbid disorders, IQ and SES), and their joined influence on AA, should be examined in future studies.

Introduction

Children with attention problems (AP) are characterized by symptoms of inattentive, hyperactive and impulsive behaviour. Children with severe symptoms are diagnosed as having attention deficit hyperactivity disorder (ADHD), which is a highly prevalent disorder during childhood (1). ADHD

has a high impact on families with affected children and poses enormous burden on society in terms of financial costs and adverse outcomes later in life (2). It is assumed that symptoms of inattentive, hyperactive and impulsive behaviour are normally distributed in the population, with ADHD positioned at the extreme end of this distribution(3–5). In this review we will use the term AP to refer to these behavioural symptoms, including the disorder ADHD.

Several studies reported an association between impaired cognitive functioning and AP in children, for example deficits in inhibition and working memory (6–11), motor flexibility (12, 13) and selective and sustained attention (14–16). However, others found the evidence for impaired cognitive functioning less convincing (17–20), and emphasized the neuro-cognitive heterogeneity among affected children (21–23).

More compelling seems the negative relation between AP and IQ performance. Friedman et al. (8) investigated in a large sample the relation between AP at several time points during childhood (age 7, 8, 9, 10, 11, 12, 13 and 14), and IQ scores at age 16, and found longitudinal correlations between −0.21 and −0.27. Similarly, Polderman et al. (24) reported significant longitudinal correlations between AP measured by teachers and parents at age 5, and IQ scores at age 12 ($r = -0.30/-0.31$). In cross-sectional designs across childhood, correlations between AP and IQ show the same pattern with a correlation of −0.30 in 5-year-old children (25), of −0.26 in 9-year-old children and of −0.34 in 12-year-old children (26). A review by Frazier et al. (27) indicated that, IQ performance is significantly lower among persons with ADHD compared with normal controls.

An interesting question is whether impaired cognitive functioning as assessed with neuropsychological assessments, or IQ tests, is also reflected in academic and educational achievement of children with AP. Educational achievement is an important predictor of socio economic status (SES) later in life, and wellbeing and health in adulthood (28). As about 5% of the world population is suffering from ADHD (1) the long-term educational outcomes of these children are highly relevant. Only one previous review (29) conducted a review and meta-analysis on ADHD and achievement. Based on calculated effect sizes of all relevant studies published between 1990 and 2006, they determined the strength of the association between ADHD and academic achievement (AA). The results of their analyses were based on 72 studies and revealed that affected subjects had a significant lower achievement then non-affected subjects.

The aim of the current review is to provide a review of studies that have addressed the *prospective* relationship between AP and AA during childhood. In contrast to cross-sectional studies as reviewed previously (29), the use of prospective studies enables to address the predictive validity of AP. Thus, these studies can determine whether AP predict academic deficits over periods in the future. Prospective studies on this topic are limited and the assessment of AP and AA vary enormously across studies. To ensure a valid and objective conclusion about the prospective association between AP and AA we performed a quality assessment for the included studies. Studies were evaluated with objective criteria as proposed by Hayden et al. (30). Based on the quality assessments, a best evidence synthesis (31) provided the strength of the prospective association between AP and AA.

In an attempt to provide an overview of the pure association between AP and AA, we excluded studies that focused on medical intervention and comorbidity. A substantial amount of children with ADHD use a medical stimulant as treatment (32), such as methylphenidate or amphetamine, to reduce their symptoms of hyperactivity and attention deficit. There is evidence that this positively influences their academic performance (33–35). Also, children with ADHD often show comorbid disorders like dyslexia (36), oppositional deviant problems (ODD), conduct disorder (CD), or anxiety (37, 38) which may lead to additional problems in educational achievement (39). Studies aiming to investigate the combination of AP with a particular comorbid disorder, were excluded from this review. Thus, for example, a study on AA for which children were recruited with ADHD and conduct disorder specifically, was excluded from this review. However, studies focusing solely on AP but including some subjects having a comorbid disorder were included in the review, as the co-occurrence is the rule rather than the exception.

Aims of the study

With this review, we aim to give a systematic overview of the literature on the prospective relation between AP and AA. Based on objective quality assessments of the included studies we intend to draw conclusions about the extent to which AP in childhood predict academic problems in the future.

Material and methods

Quality assessment

Longitudinal studies on AP and AA may encounter various biases resulting in decreased validity and generalisation of these studies. The following criteria, that were suggested by Hayden et al. (30), were considered to appraise the quality of prospective studies that were included in the current review.

Study participation and attrition. Participation rates at baseline and follow-up, causing possible differences between responders and drop-outs on key characteristics, determine a sample's representativeness. Children with AP or with cognitive impairments may be more likely to drop-out, leaving the remaining sample unrepresentative, resulting in the fact that findings can not be generalised. To allow comparison among studies and to determine a possible selection bias, a clear description of sample characteristics and differences between participants and drop-outs should be provided.

Assessment of AP. For the assessment of AP a variety of valid and reliable behaviour checklists are available. These can be completed by clinicians, parents, teachers or children themselves. Clinical diagnoses of ADHD are based on DSM-IV criteria and are typically made by psychiatrists, who use information that is collected by behaviour checklists and questionnaires, with in addition interviews and observations by trained clinicians. According to the DSM-IV there are three types of ADHD: i) Hyperactive/Impulsive type, ii) Inattentive type and iii) Combined type. Behaviour checklists vary in their concept of AP; some checklists focus on hyperactivity rather than attention deficit, while others have more items on cognitive problems. The Conner's Rating Scale for example includes four scales; 'cognitive problems', 'oppositional behaviour', 'hyperactivity', and 'overall ADHD'. However, it seems that with the commonly used checklists generally the same underlying trait is measured. A comparison between the Child Behavior Checklist (CBCL) AP scale, the Conner's ADHD scale and a DSM-IV ADHD interview showed large overlap between instruments, with correlations varying between 0.62 and 0.75 (40). In addition, it is assumed that ADHD is an extreme expression of the normally distributed trait AP, thus reflecting the same behavioural construct and underlying biological mechanisms (3–5). For the current review we therefore included studies on AP, assessed in normal population samples with behaviour checklists, as well as studies on clinical samples. When appropriately measured, a distinction was made between the subtypes hyperactivity and inattentiveness.

Assessment of AA. The concept of AA or educational status varies across studies which makes the comparison among studies rather difficult. However, they all cover the concept of AA which warranted inclusion of most measures. Truancy, suspension and expulsion were not viewed as AA as these extend beyond academic competence. Often used outcomes for AA are grade repetition, drop-out before graduation, years of formal schooling, and the need for special education. Common AA tests are the Wide Range Achievement Test-Revised (WRAT-R) consisting of three parts: reading, arithmetic and spelling (41), the Woodcock–Johnson Test of Achievement-Revised, which measures several academic skills, including reading and mathematics (42), the Peabody Picture Vocabulary Test-Revised (43) measuring receptive vocabulary, and the Peabody Individual Achievement Test (44) measuring reading and mathematics.

Confounding factors. Several confounding factors can play a role in the relation between AP and AA, for example age of the participants. AA becomes more important later in life, and for this reason AP may be less of a burden in young children than in adolescents. Gender may be another confounding factor; boys tend to have more AP than girls (45, 46), and also reading deficits (47, 48) and verbal fluency problems (49) are more common in boys than in girls. It is unclear whether this determines a gender-dependent relation between AP and academic performance but to avoid possible bias gender of the participant should be taken into account. A third potential confounding factor is IQ. Several studies showed a negative correlation of IQ performance with AP (8, 24, 25), and with ADHD (27). Also, AA is related to IQ (50, 51). To control for the possibility that cognitive competence accounts for the AP–AA association, it is advisable to control for IQ performance. Fourth, SES is a factor that might be related to academic performance. Children from low-income families enter school with lower mean academic skills and this gap might increase during childhood (52). Lastly, as described above, the use of medication and the presence of comorbid disorders may have an influence on the relation between AP and AA. Therefore, in the analyses, these factors should be taken into account.

Analysis and data presentation. A clear presentation of the data analyses and findings of a study is a necessary condition for the reader to judge the quality of a study. In addition, sample sizes must supply sufficient statistical power to draw firm conclusions on the relation between AP and AA.

To evaluate the quality of the selected studies for the current review a checklist was developed consisting of criteria as described above. Table 1 shows the items of this checklist, divided over seven domains. Every item was rated either positive (+) or negative (−) by two independent reviewers (TJCP and ACH). The scores of the reviewers were compared, where in case of any disagreement consensus was achieved by discussion. Subsequently, studies were ranked based on the number of biases. The highest quality was attained if at least 50% of the items of each domain were rated as being positive (30). A bias was present when more than 50% of the criteria of one domain had a negative score.

Best-evidence synthesis. Because of the considerable variation in AP and AA measures among studies, we performed a best-evidence synthesis instead of meta-analysis, to determine the evidence for the investigated prospective relations between AP and educational achievement. The evidence for a factor was determined by taking into account the number of studies evaluating this relation, the methodological quality of these studies, and the consistency of these studies' findings (53). Four levels of evidence, based on Sackett et al. (31) were defined (see Table 2).

Study selection

Online searches in PsychInfo, PubMed, and ISI Web of Knowledge (ISI) databases were carried out. These included published, peer reviewed studies written in English through August 2009 using the search terms "Attention Deficit Disorder with Hyperactivity" [MESH], AND "Longitudinal Studies" [MESH], AND "Educational Status" [MESH]. In PsychInfo, PubMed and in ISI a total of, respectively one, 31 and 33 studies were identified. The same search was repeated with Educational Status being replaced by "AA". This resulted in the identification of the same study in PsychInfo, 30 studies in PubMed and 30 studies in ISI. Abstracts of all studies were inspected on the following criteria: i) attention deficit, hyperactivity/

Table 1. Criteria list for the quality assessment of studies on attention problems (AP) and academic achievement (AA)

Criteria
1. Study purpose
(A) Description of a specific, clearly stated purpose of the study.
2. Study participation
The study sample represents the population of interest on key characteristics, sufficient to limit potential bias to the results.
(B) Description of the key characteristics of the study population (distribution by age, gender and ethnicity).
(C) The sampling frame and recruitment are described, including characteristics of the place of recruitment.
(D) Inclusion and exclusion criteria are described.
(E) Information about participation at baseline.
3. Study attrition
Loss to follow-up is not associated with key characteristics, sufficient to limit potential bias.
(F) Adequate (>65%) response rate.
(G) There are no important differences in key characteristics between completers and drop-outs.
4. Predictor measurement
The predictor variables are adequately measured in study participants to sufficiently limit potential bias.
(H) A clear definition or description of the measure of AP is provided.
(I) The assessment of AP is adequately valid and reliable to limit misclassification bias (Includes: assessment at age 10 or younger by adult informants, assessment at age 10 + by self-report; assessment by two or more informants; report of the reliability of the assessment).
(J) AP were assessed prior to the assessment of AA.
5. Outcome measurement
The outcome of interest is adequately measured in study participants to sufficiently limit potential bias.
(K) A clear definition of the measure of AA is provided.
(L) The measure of AA is adequately valid to limit misclassification (Includes when applicable: report of the reliability of the assessment).
6. Confounding factors
Important potential confounders are appropriately accounted for, limiting potential bias with respect to the prognostic factor of interest.
(M) Age and gender are accounted for in the analysis.
(N) IQ and SES are accounted for in the analysis.
(O) In case of clinical samples, treatment stimulants and comorbidity are accounted for in the analysis.
7. Analysis and data presentation
(P) The selected model is appropriate for the design of the study.
(Q) Presentation of the data is sufficient to assess the adequacy of the analysis.
(R) The number of cases in the multivariate analysis is at least ten times the number of independent variables in the analysis.

Table 2. Definitions of levels of evidence [Sackett et al., (31)]

Level of evidence	
Strong	Consistent findings (≥75%) in at least two high quality studies
Moderate	Consistent findings (≥75%) in one high quality study and at least one study of lower quality
Weak	Findings in one high quality study *or* consistent findings (≥75%) in at least 3 or more studies of lower quality
Inconclusive	Inconsistent findings irrespective of study quality, or less than three lower quality studies available

≥75%, at least 75% of the findings of studies investigating a specific relation between AP and academic achievement had to agree on existence and direction of the relation.

impulsivity, or AP were predictor variables, ii) academic or educational achievement were outcome measures, iii) a longitudinal study design, iv) samples including children or adolescents for AP measures, v) no medical manipulation (e.g. methylphenidate) and vi) no focus on AP in combination with a specific comorbid disorder. This resulted in one relevant study through PsychInfo, 15 relevant studies through PubMed, and 14 through ISI, of which two studies of PubMed and ISI overlapped. Of this total of 28 studies, the reference lists of included reviews and most recent studies (2007 and 2008) were inspected to identify supplementary studies. This resulted in the identification of two additional studies. The author of an initially detected paper (Mannuzza) provided us with five extra studies by this author. Finally, based on reference lists of detected studies, a search was done on the websites of Journal of School Psychology, Journal of Educational Psychology, and Developmental Psychology of which the latter journal gave one result. Of this total of 36 studies, 20 studies were excluded because they were reviews ($n = 3$), because of overlap in samples ($n = 6$), because of duplicate citation ($n = 1$), because of a focus on comorbid disorders ($n = 5$), because medical treatment was manipulated ($n = 1$), because AA was not an outcome ($n = 2$), and because studies were not prospective but retrospective ($n = 2$), leaving 16 studies to review. Table 3 provides a summary of all included studies in alphabetical order of first author.

Results

Descriptives of measures and samples

The AA outcome measures could be distinguished in achievement tests ($n = 6$) and educational attainment (i.e. years of education, graduation from high school, and attending college for example; $n = 7$). In three studies a combination of both was used. Another distinction was the use of normal population samples ($n = 6$) and the use of clinical samples (n = 10). Both type of studies used achievement tests as much as educational attainment as an outcome. The hyperactive subtype of ADHD was subject in ten studies, the inattentive subtype in four studies, the combined type in two studies, and no distinction between the subtypes was made in five studies. Most studies used subjects of both sexes. In the normal population samples, the distribution of males and females was approximately equal while in the clinical samples boys were over-represented (varying from 70 to 93%). Three clinical studies had (almost) only male subjects (54, 55, 65) and two clinical studies had only female subjects (64, 69).

Quality assessments

Table 4 shows the results of the quality assessments; studies are ordered from high to lower quality. Three out of 16 studies had no bias (i.e. satisfying at least 50% of the criteria of each of the seven domains of the checklist) and six studies contained one bias (i.e. not satisfying the 50% of the criteria of one domain). In the remaining seven studies biases varied from two to four.

Notable limitations concerned information on the recruitment and follow-up of participants, and the inclusion of advisable covariates. About half of the studies did not report on attrition and possible differences between participants and drop-outs, and in most studies a clear description of baseline participation was missing. The assessment of AA and AP was in most studies sufficient although the assessments of AP often lacked information of multiple raters. The latter is important as multiple raters can account for the situational variation in children's behaviour (82, 83). IQ and SES were included in half of the studies. In all clinical studies, except two, the covariates comorbidity and medication were not included. Lastly, five studies had a bias on the analysis and data presentation.

The predictive relationship between attention problems and academic achievement

Three studies were identified as having no bias (56, 64, 66). Remarkably, two of these studies reported a negative association of AA with inattentive behaviour, but not with hyperactive behaviour,

Table 3. Details of included studies on attention problems (AP) and academic achievement (AA)

Study	Age at assessment AP	Age at assessment AA *n* of subjects at that time (% males)	AP measure	AA measure	Results	Effect size
(Barkley et al., 2006) (54)	4–12	19–25 *n* = 149 cases, 76 controls (91%)	Conners Rating Scale- Revised (CRS-R) Werry-Weiss-Peters Activity Rating Scale (WWPARS)	years of education grade points average graduation from high school	Hyperactivity predicted failure to graduate from high school Hyperactive group had less years of education and had a lower grade point average compared to controls	ß = 0.051, OR 1.05, ($P < 0.001$)
(Biederman et al., 1996) (55)	6–17	4 years after first assessment *n* = 128 cases, 109 controls (100%)	DSM-III interviews	Wide Range Achievement Test-Revised (WRAT-R) Gilmore Oral Reading Test repeated grades placement in special classes need for tutoring/help	ADHD children were significantly impaired on all achievement tests compared with controls. The need for extra help, repeated grades and placement in special classes increased significantly during follow-up.	Not available
(Breslau et al., 2009) (56)	6	17 *n* = 693 normal population subjects (47%)	Teacher's Report Form (TRF), AP scale	Woodcock–Johnson Test of Achievement-Revised (WJ-R)	Attention problems were significantly associated with reading and mathematics after correcting for IQ and family factors	Reading: ß = −0.31, ($P < 0.001$) Maths: ß = −0.34, ($P < 0.001$)
(Currie & Stabile, 2006) (57)	4–11	4 to 6 years after first assessment N = ∼7.548 normal population subjects (50%)	8 questions on hyperactivity 5 questions on hyperactivity of the NLSY Behaviour Problems Index	Peabody Individual Achievement Test (PIAT) Canadian achievement tests grade repetition special education	Negative effects of hyperactivity on test scores and educational attainment.	Not available
(Duncan et al., 2007) (58)	4–6	8–14 N = ∼34.837 normal population subjects (50%)	questions on hyperactivity Child Behavior Check List (CBCL), AP scale Teacher's Report Form (TRF), AP scale Rutter Health and Behaviour Chekclist, inattention scale	achievement tests on reading and mathematics PIAT Woodcock–Johnson Test of Achievement-Revised (WJ-R) Number Knowledge Test Edinburgh Reading Test University of Bristol Math Test	Attention *skills* are a significant predictor for reading and mathematics	Reading: $r = 0.08$, ($P < 0.001$) Maths: $r = 0.11$, ($P < 0.001$)
(Fisher et al., 1993) (59)	4–12	8 years after first assessment *n* = 100 cases (88%), 60 controls (93%)	CRS-R WWPARS	WRAT-R	Hyperactive subjects displayed significant poorer academic skills than control subjects on reading, spelling and arithmetic	Not available
(Flouri, 2007) (60)	5	26 *n* = 6.522 normal population subjects (45%)	Rutter 'A' Health and Behavior Checklist	highest level of education	Hyperactivity is related to low educational attainment, with a stronger effect in high-stimulation environments	ß = −0.08, ($P < 0.001$)
(Howell et al., 1985) (61)	3rd, 4th, 5th grade in elementary school	9th grade, 12th grade, 3 years after high school *n* = 319 normal population subjects (47%)	21 questions on attention deficit related behaviour (Huessy & Cohen, 1976)	reading problems remedial English graduation from high school education beyond high school	Children exhibiting attention deficit related behaviour in elementary school had more often reading problems, remedial English lessons, dropped out of school before graduation more often, and were significantly less likely to have additional education beyond high school	Not available

Table 3. Continued

Study	Age at assessment AP	Age at assessment AA *n* of subjects at that time (% males)	AP measure	AA measure	Results	Effect size
(Lambert, 1988) (62)	Children in elementary school *n* = 166 cases and 201 controls	17–18 *n* = 301 (? cases and ? controls)* (? %)	a medical diagnosis of hyperactivity/inattention and treatment for the condition	special education graduation from high school college attendance	Children with hyperactivity had significantly more often special education Children with hyperactivity and inattention were significantly less likely to graduate from high school Children with inattention significantly more often failed to go on to college	$r = 0.25$, ($P < 0.05$) $r = -0.37$ and -0.28 resp., ($P < 0.05$) $r = -0.18$, ($P < 0.05$)
(Latimer et al., 2003) (63)	7–11	4 years after first assessment *n* = 115 cases (83%), 59 controls (70%)	CRS-R Revised Parent Version of the Diagnostic Interview for Children and Adolescents (DICA-R-P)	WRAT WJ-R	Significant association between childhood ADHD and AA	$r = -0.37$, ($P < 0.001$)
(Lee & Hinshaw, 2006) (64)	6–13 *n* = 140 cases and 88 controls	5 years after first assessment *n* = 209 (? cases and ? controls)* (0%)	Swanson, Nolan, and Pelham Questionnaire (SNAP)	Wechsler Individual Achievement Test (WIAT)	Inattention significantly predicted AA, but hyperactivity did not after correcting for IQ, comorbid disorders, age and family income	Inattention: ß = −0.32, ($P < 0.01$) Hyperactivity: ß = 0.03, ($P = 0.77$)
(Mannuzza et al., 2002) (65)	6–12	10–12 years after first assessment *n* = 232 cases, 178 controls (100%)	CRS-R WWPARS DSM-II hyperkinetic reaction of childhood diagnosis	highest grade completed	Children with hyperactivity had a significant lower educational outcome	Not available
(Massetti et al., 2008) (66)	4–6	8 years after first assessment *n* = 125 cases (80%), 130 controls (80%)	DSM-III-R, DSM-IV diagnosis DISC Impairment Rating Scale (IRS)	WJ-R (3 scales: Reading, Mathematics, Dictation Scale)	After correcting for IQ, comorbid disorders and family income, only the inattentive subtype (but not the hyperactive subtype) children had significantly lower reading scores, lower math scores, and lower dictation (i.e. spelling) scores compared with controls	Inattention: Reading: ß = −7.00, $z = -2.28$, ($P < 0.03$), Cohen's $d = -1.16$ Maths: ß = −6.49, $z = -3.34$, ($P < 0.001$), Cohen's $d = -1.30$ Dictation: ß = −6.90, $z = -2.86$, ($P < 0.005$), Cohen's $d = -1.46$ Hyperactivity: Reading: ß = 3.26, $z = 1.40$, ($P = 0.16$) Maths: ß = 0.40, $z = 0.18$, ($P = 0.36$) Dictation: ß = 0.83, $z = 0.38$, ($P = 0.70$)

Table 3. Continued

Study	Age at assessment AP	Age at assessment AA *n* of subjects at that time (% males)	AP measure	AA measure	Results	Effect size
(McCormick, 2004) (67)	6–15	18 *n* = 73 cases (78%)	DSM-III-R, DSM-IV diagnosis	completion high school attendance college	77% of the ADHD subjects completed high school, of these 50% attended college	Not available
(Merrell & Tymms, 2001) (68)	4–5	6–7 *n* = 4.148 normal population subjects (52%)	DSM-IV based questionnaire	reading and mathematics tests from Performance Indicators in Primary Schools (PIPS)	Subtypes of ADHD (inattentive and hyper active resp.) are negatively related to reading and math scores	Inattention: Reading: Cohen's *d* = −1.07 Maths: Cohen's *d* = −1.18 Hyperactivity: Reading: Cohen's *d* = −0.58 Maths: Cohen's *d* = −0.36
(Young et al., 2005) (69)	6–7	14–16 *n* = 47 cases and 23 controls (0%)	Rutter 'A (2)' and 'B (2)' Health and Behavior checklist	effort in school work confidence in school performance	Hyperactivity predicted academic problems	Not available

Abbreviations and references of instruments for AP and AA in alphabetical order:

CBCL = Child Behavior Checklist [Achenbach, 1991a (70)]; CRS-R = Conners Ratings Scale-Revised [Goyette et al., 1978 (71)]; DICA-R-P = Revised Parent Version of the Diagnostic Interview for Children and Adolescents [Welner et al., 1987 (72)]; DISC = Diagnostic Interview Schedule for Children [Shaffer et al., 1983 (73)]; DSM = Diagnostic and Statistical Manual of Mental Disorders [American Psychiatric Association, 1994 (74)]; IRS = Impairment Rating Scale [Fabiano et al., 2006 (75)]; NLSY = National Longitudinal Survey of Youth; PIAT = Peabody Individual Achievement Test [Dunn & Markwardt, 1970 (76)]; PIAT-R = Peabody Individual Achievement Test-Revised [Markwardt, 1989 (44)]; PIPS = Performance Indicators in Primary Schools, see Curriculum Evaluation and Management Centre, University of Durham (http://www.cem.dur.ac.uk); Rutter 'A' Health and Behavior Checklist [Rutter et al., 1970 (77)]; SNAP = Swanson, Nolan, and Pelham Questionnaire [Swanson, 1992 (78)]; TRF = Teacher's report Form [Achenbach, 1991b (79)]; WIAT = Wechsler Individual Achievement Test [Wechsler, 1992 (80)]; WJ-R = Woodcock–Johnson Test of Achievement-Revised [Woodcock & Johnson, 1990 (42)]; WRAT-R = Wide Range Achievement Test-Revised [Wilkinson, 1993 (41)]; WWPARS = Werry-Weiss-Peters Activity Rating Scale [Werry & Sprague, 1970 (81)].

ß-coefficients come from linear regression analyses, or (Barkley et al., 2006) (54) logistic regression analyses.

*unclear how many cases and how many controls during follow-up.

Table 4. Results of the quality assessment of studies on attention problems (AP) and academic achievement (AA)

	Domain	1	2				3		4				5		6				7			
	Criterium	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	No. biases
	Studies																			
1	Breslau et al. 2009 (56)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	0
2	Lee & Hinshaw, 2006 (64)	+	+	+	+	−	+	+	+	+	+	+	+	+	+	+	+	+	+	0
3	Massetti et al. 2008 (66)	+	+	+	+	−	+	+	+	+	+	+	+	+	+	+	+	+	+	0
4	Barkley et al. 2006 (54)	+	+	+	+	−	+	−	+	−	+	+	+	−	−	−	−	+	+	1
5	Biederman et al. 1996 (55)	+	+	+	+	−	+	+	+	+	+	+	−	+	+	−	+	−	−	1
6	Duncan et al. 2007 (58)	+	+	+	−	−	−	−	+	+	+	+	+	+	−	+	+	+	+	1
7	Latimer et al. 2003 (63)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	−	+	−	−	1
8	Mannuzza et al. 2002 (65)	+	+	+	+	−	+	−	+	+	+	+	+	+	−	−	+	−	+	1
9	Young et al. 2005 (69)	+	+	+	+	+	+	+	+	−	+	+	−	+	−	−	+	+	+	1
10	Fisher et al. 1990 (59)	+	+	+	+	−	−	−	+	−	+	+	−	−	+	−	+	+	+	2
11	Flouri, 2007 (60)	+	−	−	−	+	−	−	+	−	+	+	−	+	+	+	+	−	+	2
12	Howell et al. 1985 (61)	−	−	+	+	+	−	+	+	−	+	−	+	+	−	+	−	−	+	2
13	Merrell & Tymms, 2001 (68)	+	−	+	+	+	−	−	+	−	+	+	+	+	−	−	−	+	+	2
14	Lambert, 1988 (62)	+	−	−	−	−	+	+	−	−	+	+	+	+	+	−	−	−	−	3
15	McCormick, 2004 (67)	+	+	+	−	−	+	−	+	−	+	+	+	−	−	−	−	−	−	3
16	Currie & Stabile, 2006 (57)	−	+	−	−	−	−	−	−	−	+	+	+	+	−	+	+	+	+	4

Bias is defined as negative ratings on more than 50% of the criteria for a specific domain.

Domain: 1, aim of the study; 2, study participation; 3, study attrition; 4, AP measurement; 5, AA measurement; 6, confounding factors; 7, analysis and data presentation (see Table 2); '+', study was rated positive on criterion; '−', study was rated negative on criterion.

after correction for confounding factors. Lee and Hinshaw (64) studied predictors of adolescent functioning, including AA, in 209 girls (ADHD cases and controls) aged 6 to 13 years old, who participated in summer programmmes during childhood. The Wechsler Individual Achievement test, assessed five years after the AP assessment, was used as outcome variable. After controlling for confounding factors such as age, comorbid disorders, family income and intelligence, only inattentive behaviour was significantly associated with academic impairments, but not hyperactivity. In the case-control study by Massetti et al. (66), 255 children, with boys being over-represented (80%), were followed over eight-years time. DSM diagnoses were assessed at age 4 to 6 years old. AA was measured with the Woodcock–Johnson Test of Achievement-Revised (WJ-R). This study included the covariates intelligence, ethnicity, family income, age, sex and comorbid disorders. The results were similar as presented by Lee and Hinshaw (64); after correction for the confounding factors, only the inattentive subtype of ADHD, but not the hyperactive subtype, predicted academic underachievement. In the third study (56) the WJ-R was assessed in an ethnically diverse population sample of almost 700 children when they were 17 years old. At the age of 6, AP were assessed with the CBCL and TRF. AP predicted significantly diminished AA in adolescence, relative to expectations on cognitive abilities, as IQ was included as covariate in the analyses.

For six studies in this review one bias was reported. Contrary to Lee & Hinshaw (64) and Massetti et al. (66), Biederman et al. (55) did find a significant, negative association between hyperactivity and achievement test scores, after the inclusion of IQ and SES as covariates. In this study, the age of AP assessment ranged from 6 to 17 years old; achievement scores on the Wide Range Achievement Test-Revised (WRAT-R) and Gilmore Oral Reading Test were assessed four years after the first assessment. Three other studies that investigated the predictive validity of the hyperactive subtype of ADHD specifically did not include covariates like IQ and SES. These studies reported significant lower educational achievement in terms of highest grade completed or grade points average, assessed in young adult males (54, 65), and in terms of school effort and confidence in school performance, assessed in girls at ages 14 to 16 years old (69). Latimer et al. (63) measured ADHD symptoms in children aged 7 to 11 years old with the Conner's. Four years later, they found significant lower scores on the WRAT-R and WJ-R in affected children, compared with controls. Using six large population cohorts ($n = \sim 34\,000$), Duncan et al. (58) showed that AP, assessed between ages 4 and 6 with various behaviour questionnaires, significantly predicted lower AA test scores. The results applied to all cohorts, to boys and girls, and to children from high and low socioeconomic backgrounds. Finally, seven studies contained two to four biases. The conclusions of these studies were in line with the studies as described above, namely that AP were negatively related to AA, except for one study by McCornick (67). The author of this study

concluded that with comprehensive treatment child ADHD patients were not at risk for academic underachievement; 77% of his patients completed high school, and of these, 50% attended college.

The best evidence synthesis used in this review (31), requires for a strong association between AP and AA consistent findings in at least two studies with no bias. A moderate association is present when consistent findings are present in one study with no bias and at least one study with one (or more) bias. Based on the current findings, our overall conclusion is that the inattentive symptoms of ADHD are a strong predictor of lower AA while the hyperactive symptoms are a moderate predictor of lower AA.

Discussion

This review presents evidence for a negative prospective relation between AP and AA. The strongest relation was present for the inattentive symptoms of ADHD. After the correction for comorbidity, IQ and SES the association with hyperactive symptoms was non-significant in two studies. One explanation might be that symptoms of hyperactivity decline with increasing age while inattentive symptoms show a relatively constant pattern (84, 85). Persistent inattentiveness will likely have a negative influence on AA performance, independent of IQ and SES. However, a 4-year-follow-up study by Biederman et al. (55) did find a significant relation between AA performance and hyperactivity while controlling for IQ and SES.

Several options, varying from environmental aspects, to biological and genetically predisposed factors, may explain the negative relationship between AP and educational attainment. Latimer et al. (63) speculated that 'academic underachievement among children diagnosed with ADHD in elementary school may be explained by a failure to develop basic skills during the preschool years'. In line with this, Breslau et al. (56) argues that the negative influence of AP likely begins in the early grades, with consequently a limited ability to acquire basic skills that are necessary for the development of higher cognitive skills later in school. Also Duncan et al. (58) suggested that the time that children are participating in academic endeavors and learning activities (e.g. that is dependent of their attention skills) is highly predictive for their academic outcomes. Also, the importance of a capable teacher is emphasized; a good teacher achieves a climate in which children are engaged and motivated for learning, leading to positive school adjustments (86). Flouri (60) suggested that impoverished environments, in terms of resources (i.e. low income) or in terms of cognitive stimulation (i.e. parental depression of low parental education) predicted lower academic attainment in children with AP.

Neuropsychological theories that addressed the causal mechanisms for ADHD take a more biological approach in their interpretation of cognitive impairments related to AP. They point to neurological dysfunctions in prefrontal regions that have an influence on regulatory control (6, 87), effort, arousal and motivation (88), and learning and conditioning (89). Each of these processes will most likely have an effect on academic performance. Several brain imaging studies confirmed that ADHD is associated with differences in brain activation patterns and brain volume differences in prefrontal neural circuits, caudate nucleus and cerebellum (for a nice overview see Steinhausen (90). Shaw et al. (91) reported an association between cognition and the trajectory of cortical development, primarily in frontal regions. Moreover, in an accompanying study, Shaw et al. (92) showed that children with ADHD have relative cortical thinning in regions important for attentional control (i.e. medial and superior prefrontal and precentral regions).

Three twin studies showed that in childhood, variation in general intelligence (IQ) was genetically correlated with variation in AP (24–26), pointing to a shared set of genes that has an influence on AP and intelligence. Candidate genes might be involved in the dopaminergic pathways of the prefrontal cortex. Mill et al. (93) tested whether the *DRD4* seven-repeat allele and the *DAT1* ten-repeat allele were associated with variation in intelligence among children with ADHD. They found evidence for this association in two independent samples, from New Zealand and Britain. However, a replication of these findings in independent samples by Genro et al. (94) and Sonuga-Burke et al. (95) failed to find this association.

Comorbid disorders are an additional obstacle for the educational development of children affected with AP. In this review we aimed to distinguish the effect of AP on AA from comorbid disorders. We therefore choose studies without a focus on comorbidity, and the aspiration that correction for comorbidity was included in any case. However, co-occurrence is often present; 60% of children with ADHD also has oppositional disorder (ODD), 15% has conduct disorder (CD), and about 30% show mood and anxiety disorders (96). Especially the highly prevalent co-occurrence

with ODD, with symptoms of impatience and low frustration tolerance, might have an important influence on achievement skills. Moreover, impaired executive functioning is reported in children with CD and ODD (97), increasing the risk of academic underachievement.

Low academic attainment is a salient adverse outcome, as it has great impact on potential lifetime earnings, access to higher education, employment possibilities, health and wellbeing in adulthood (28, 98). To counsel children that suffer from ADHD sufficiently, we need to develop effective intervention strategies. Counseling should not solely be limited to the children and their families. For example, there is a moderate correlation between parental and teacher ratings of AP, pointing to the situational variation in children's behaviour. Parents have unique information about the child's behaviour in the family environment while teachers can report on problems that are specific to the classroom (82, 99). Moreover, particularly the teacher may play an important role in the educational development of affected children. In a recent paper, Jitendra et al. (100) present convincing evidence that teacher mediated interventions in reading and mathematics enhances AA in children with ADHD. Hence, an important aspect of intervention should be interaction with the school.

Considerations

We based our conclusions on studies that were objectively quantified by two independent raters (30). Although in this way we aimed to limit spurious conclusions, our findings should be taken with caution. First, the three studies with no bias, thus having more weight in our conclusions, differed in study characteristics. The majority in the sample in the study by Massetti et al. (66) were boys, while Lee & Hinshaw (64) examined girls. Also the age of AP assessment differed between these studies. Children were assessed at age 4–6 years in the study of Massetti et al. (66) while they were 6–13 years old in Lee & Hishaw's (64) study. AP may be viewed as less deviant or disturbing in young children, when they visit Kindergarten (i.e. 4–6 years old), compared with when they are older and visit primary school (i.e. 6–13 years). In this period educational tasks demand much more attention skills, and allow for less inattentiveness, (hyper) activity and physical movements, hence ADHD symptoms might be rated as more severe. Another point of concern involves the small sample size of inattentive children ($n = 14$) in the study by Massetti et al. (66). The sample used by Breslau et al. (56) was large however ($n = 693$), and consisted of a mixed population, according to gender and ethnicity.

Second, IQ and SES were in our opinion important covariates in the prospective relation between AP and AA. However, as there is a significant relation between ADHD, IQ and SES, part of the variance in the outcome measure that is actually attributable to ADHD, may be removed when statistical controlling for IQ and SES. Half of the studies in this review did not control for IQ and SES, and all, except one (67), reported a negative relation between AP and educational achievement. Moreover, Duncan et al. (58) showed that the negative association in their study was similar for children from low and high socioeconomic backgrounds. To get more insight in the actual relation between AP and related factors (i.e. comorbid disorders, IQ and SES), and their joined influence on AA, future studies should thoroughly examine the causality in these relationships.

Furthermore, our search for papers was restricted to papers that were included in electronic databases that are considered relevant for the topic of our review. Therefore, we may have missed studies that do not fulfill these requirements and that were not identified during our additional reference checking. And lastly, to reduce arbitrariness in the quality appraisal of the studies and in the levels of evidence for the various relations between AP and AA, we based our definitions on recommendations by Hayden et al. (30) and Sackett et al. (31). However, any system for defining level of quality or evidence will be subject to some randomness.

Acknowledgement

All authors contributed towards the conception and design of the project, a critical review of the manuscript, and approved the final version. TJCP and ACH performed the quality assessments. TJCP wrote the manuscript, and is guarantor.

Declaration of interests

All authors declare that the answer to the questions on your competing interest form are all No and therefore have nothing to declare.

Funding

This work was supported by NWO 904-57-94, NWO/SPI 56-464-14192; NWO 480-04-004; NIMH, RO1 MH58799-03. TJCP is funded by Sophia Foundation for Scientific Research (SSWO, no. 562).

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