

**CHILDHOOD AND ADOLESCENT HYPERACTIVITY-INATTENTION
SYMPTOMS AND ACADEMIC ACHIEVEMENT 8 YEARS LATER:
THE GAZEL YOUTH STUDY**

Galéra Cédric (1,2)

Melchior Maria (3)

Chastang Jean-François (3)

Bouvard Manuel-Pierre (1)

Fombonne Eric (4)

Affiliations:

(1) Child Psychiatry Department, Charles Perrens Hospital, University Victor Segalen
Bordeaux 2, Bordeaux, France

(2) INSERM, U897, Equipe Avenir Prévention et prise en charge des traumatismes,
Centre de Recherche Epidémiologie et Biostatistique, Bordeaux, France

(3) INSERM, U687, Villejuif, F-94807, France ; Université Paris XI, IFR69, Villejuif, F-
94807, France

(4) McGill University, Montreal Children's Hospital, Child Psychiatry, Montreal, Canada

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Hyperactivity-inattention and academic achievement

Corresponding author:

Dr. Cédric Galéra

Pôle de pédopsychiatrie universitaire, Centre Hospitalier Charles-Perrens, 121 rue de
la Béchade, 33076 Bordeaux, France

Tel.: +33 556566719; fax: +33 556561736; E-mail: cedric.galera@u-bordeaux2.fr

Word count: 4400

Abstract

Background: Children with Attention Deficit/Hyperactivity Disorder (ADHD) are at risk of negative academic outcomes. However, relatively few studies in this area have been based on long-term longitudinal designs and community-based settings. This study examines the link between childhood hyperactivity-inattention symptoms and subsequent academic achievement in a community setting, controlling for other behavioural symptoms, socioeconomic status and environmental factors at baseline.

Methods: The sample consisted of 1264 subjects (aged 12 to 26 years at follow-up) recruited from the longitudinal GAZEL youth study. Psychopathology, environmental variables and academic outcomes were measured through self-reports. Multivariate modelling was performed to evaluate the effects of childhood hyperactivity-inattention symptoms and other risk factors on academic achievement 8 years later.

Results: Hyperactivity-inattention symptoms independently predicted grade retention (adjusted OR=3.58, 95%CI:[2.38-5.39]), failure to graduate from secondary school (adjusted OR=2.41, 95%CI:[1.43-4.05]), obtaining a lower-level diploma (adjusted OR=3.00, 95%CI:[1.84-4.89]), and lower academic performances. These results remained significant even after accounting for school difficulties at baseline. Negative academic outcomes were also significantly associated with childhood symptoms of conduct disorder, even after accounting for adjustment variables.

Conclusions: This longitudinal survey replicates, in a general population-based setting, the finding of a link between hyperactivity-inattention symptoms and negative academic outcomes.

Keywords: Epidemiology; Longitudinal cohort; Childhood, adolescence and young adulthood; Attention-deficit/hyperactivity disorder; Academic achievement.

Introduction

Attention Deficit/Hyperactivity Disorder (ADHD) is the most common developmental disorder, affecting 3 to 5% of school-aged children (Barkley, 1998). This early-onset condition is characterized by persistent and impairing symptoms of inattention, hyperactivity and impulsivity. In a majority of cases, the disorder persists into adolescence and adulthood (Biederman et al. 1998). ADHD is a major mental health issue owing to its association with a range of adverse psychosocial outcomes through the lifespan, including psychiatric comorbidity, antisocial behaviours and substance use disorders (Spencer et al. 2007).

As recently reviewed by Loe & Feldman (2007), several studies have found a significant link between ADHD and negative academic and educational outcomes. In particular, children with ADHD have been shown to display poor academic functioning with poor reading and math scores (Barry et al. 2002; Biederman et al. 1996), higher rates of grade retention (Barkley et al. 1990), lower rates of high school graduation and post-secondary education (Mannuzza et al. 1993). However, those surveys were somewhat limited. First, many reports used samples of clinic-referred ADHD children and adolescents, thus introducing a selection bias and limiting the generalizability of the findings. Second, most of the investigations examined populations with young age ranges, precluding consideration of long-term academic outcomes. Third, a circularity bias might have arisen from numerous studies. Indeed, the clinical definition of ADHD in the DSM-IV demands the presence of functional impairment, generally defined in terms of performance and behaviour at home and/or school. Even if DSM criteria do not necessarily include school problems, there is a possibility that in some instances school problems are associated with the definition of caseness. If school problems are considered at baseline, they are more likely to be present at follow-up and subsequently to produce spurious associations. Finally, possible confounding variables such as comorbidity and environmental conditions have not always been well addressed in the available reports.

In addition to ADHD, other risk factors are likely to contribute to academic impairment. Conduct Disorder (CD), which is characterized by persistent patterns of violence and rule-breaking behaviours, and is frequently comorbid with ADHD, has been linked to academic underachievement, especially during adolescence (Hinshaw, 1992). Nevertheless, a controversy remains in the literature since some reports have shown that once comorbid ADHD is taken into account, the specific association between CD and underachievement may disappear, suggesting that links with academic problems may be mediated by attentional difficulties (Fergusson & Horwood, 1995; Rapport et al. 1999). Internalizing problems such as anxiety and depression might also heighten the risk of negative academic outcomes (Maughan & Carroll, 2006; Van Ameringen et al. 2003). Environmental risk factors, including low family socio-economic status, parental psychopathology and parental separation, may also increase the likelihood of academic underachievement (Ackerman & Brown, 2006; Weissman et al. 1997). Identifying risk factors for academic underachievement is of major importance since poor academic achievement is a persistent correlate of low self-esteem, interpersonal difficulties and antisocial behaviours, which put individuals on adverse trajectories and lead to lower occupational insertion, higher use of social welfare, higher rates of incarceration and a greater burden to society (Karloly et al. 2005; Stone & La Greca, 1990).

In this longitudinal community study, our aim was to examine the link between childhood hyperactivity-inattention symptoms and academic achievement 8 years later, controlling for baseline psychiatric comorbidity and environmental risk factors. We hypothesized that childhood hyperactivity-inattention symptoms would be an independent risk factor for subsequent negative academic outcomes and that other factors, particularly conduct disorder symptoms, would independently contribute to negative academic outcomes.

Methods

Participants

Subjects were drawn from the GAZEL Youth cohort study set up in 1991 to investigate mental health and psychosocial factors in a large, nationwide sample of French youths. All participating youths had a parent participating in the GAZEL cohort study, a long-term longitudinal survey of the health of employees of France's National Electricity and Gas Company (EDF-GDF, abbreviated GAZEL) (Fombonne & Vermeersch, 1997a; Goldberg et al. 2007).

The GAZEL Youth cohort sample was selected to represent the socio-demographic characteristics of French youths. The sample was stratified by socio-economic status and family size according to 1991 census data using the official social class codification system (see Fombonne & Vermeersch, 1997a). Data were collected through questionnaires mailed to the parents in 1991 and at follow-up in 1999. In 1991, data were obtained on 2582 (aged 4-18 years) of the 4335 eligible youths (62.2%). Eligible youths and study sample youths were found to be comparable for most socio-demographic background characteristics (Fombonne & Vermeersch, 1997a). In 1999, 1264 parents (49%) provided follow-up data on their children. Response rates are comparable to other mental health surveys conducted in France (Alonso et al. 2004). There were no significant difference between follow-up participants and non-participants with regard to baseline hyperactivity-inattention symptoms ($t=0.68$, $p=0.50$), anxious/depressed symptoms ($t=-1.42$, $p=0.15$), conduct disorder symptoms ($t=1.61$, $p=0.11$), oppositional defiant disorder symptoms ($t=-0.17$, $p=0.87$), total CBCL problems ($t=-0.36$, $p=0.72$), parental marital status ($\chi^2=1.44$, $p=0.23$), and parental psychopathology ($\chi^2=1.87$, $p=0.17$). However, participants came from higher socio-economic backgrounds ($\chi^2=4.98$, $p<0.03$), were younger ($t=3.76$, $p<0.001$) and were more often female ($\chi^2=7.05$, $p<0.01$). An overview of the methodology and previous research findings can be found elsewhere (Fedorowicz & Fombonne, 2007; Fombonne & Vermeersch, 1997a; Fombonne &

Vermeersch, 1997b, Galéra et al. 2005; Galéra et al. 2008a; Galéra et al. 2008b; Melchior et al. 2008).

Measures

Childhood psychopathology at baseline

Childhood psychopathology was assessed in 1991, when parents completed the Child Behavior Checklist (CBCL) (Achenbach, 1991). The French version of the CBCL was validated in previous clinical and epidemiological studies (Fombonne, 1991; Fombonne, 1994) and in a direct US-French comparative study (Stanger et al. 1994). This widely used tool includes 118 items on behaviour problems in the preceding six months. Each problem item is coded 0 to 2. The CBCL makes it possible build two types of scales: (1) empirically-based scales (based on factor analyses that identify syndromes of co-occurring problem items); and (2) DSM (Diagnostic and Statistical Manual of Mental Disorders, APA, 1994) oriented scales (constructed from problem items that resemble DSM criteria for categorical diagnosis). DSM-oriented scales were proposed by Achenbach & Rescorla (2001) as proxies of DSM diagnostic categories. They are built with items that do not include all DSM criteria but they are viewed as satisfactorily consistent with DSM categories. By summing scores of the item scales, it is possible to generate quantitative scores for specific dimensions of child and adolescent psychopathology. As previously described (Galéra et al. 2005), among participants with less than one third of items missing on each CBCL scale, we imputed missing data by using the mean score on present items.

Hyperactivity-inattention symptoms were ascertained using the empirically based scale for attention problems. We kept a single combined variable since factor analysis of the CBCL did not yield separate factors for inattention and hyperactivity-impulsivity (Achenbach, 1991). Table 1 lists the specific items used to create the hyperactivity-inattention symptoms variable and provides Cronbach's α . The item "poor school work" was dropped from the

original scale to avoid a circularity bias when examining the link between Hyperactivity-inattention symptoms and subsequent academic outcomes. We generated a dichotomous variable (high and low symptom levels) by using the 90th percentile of the score distribution, which is the recommended cut-off to differentiate cases and non-cases in community samples (Bird et al. 1987; Fombonne, 1989).

To take into account potential confounders and effect modifiers, we also accounted for baseline psychiatric comorbidity using the following measures: (1) symptoms of conduct disorder, using the DSM-oriented scale; (2) symptoms of oppositional defiant disorder (ODD), using the DSM-oriented scale; and (3) symptoms of anxiety/depression, using the corresponding CBCL empirically based scale. We gave preference to CD/ODD DSM-oriented scales rather than the aggressive/delinquency empirically-based scales. Indeed, aggressive/delinquency empirically based scales reflect a distinction between aggressive and non-aggressive conduct problems. By contrast, the DSM combines aggressive and non aggressive conduct problems into the single category of Conduct Disorder (Achenbach et al. 2003). Since we wanted to assess the moderating role of Conduct disorder symptoms on the relationship between Hyperactivity-inattention symptoms and academic outcomes, it appeared appropriate to use the CD/ODD DSM-oriented scales. Table 1 details each scale used in this study.

Youths' school difficulties previous to baseline

A CBCL question assessed the presence of school difficulties prior to baseline (has had any academic or other problem in school: yes versus no).

Parental characteristics at baseline

Data on parental characteristics (marital status: divorced/ separated/ widowed/ single versus married/cohabiting; socio-economic status: familial income of < 5200 euros per year per capita versus \geq 5200 euros per year; psychological problems: frequently depressed or

treated for depression or sleep-related problems: yes versus no) were obtained from the GAZEL cohort study files.

Youths' academic outcomes at follow-up

Participants' current situation (in secondary school, in university/college, in technical/professional training, job seeker, employed or other) as well as academic outcomes were reported by the parent in 1999. In this study, we used the following outcomes: 1) grade retention assessed during participant's entire schooling (ever repeated a grade versus never repeated a grade); 2) secondary school graduation exam ("baccalaureate") (yes versus no); 3) educational underachievement (no diploma or technical/professional diploma versus general secondary school diploma or above); 4) global academic performance (performance in each of the following subjects between ages 12 to 16: "reading, French, or language arts", "arithmetic or math", "sciences" and "foreign language" was assessed as "failing", "below average", "average" or "above average", coded 1-4; these dimensions were then summed and the score was standardized to a score varying from 0 to 10). We distinguished technical/professional education from general education, because in France general education is considered superior to vocational training. We studied grade retention in the entire sample since the outcome considered was a lifetime history of grade retention. General secondary school diploma and educational underachievement were only studied among participants aged 18 or older at follow-up, as this is the typical age of secondary school graduation in France. We studied academic performance between ages 12 and 16 in the entire study sample.

Ethical approval

The GAZEL youth study was reviewed and approved by the French National Committee for data protection (CNIL: Commission Nationale Informatique et Liberté). This committee guarantees that protocols of epidemiological investigations comply with ethical and legal criteria for human research.

Statistical analyses

We first described sample characteristics and prevalence estimates for academic outcomes. We then performed multivariate regressions (logistic or linear models) for each dependent variable. We estimated the strength of the association between childhood Hyperactivity-inattention symptoms and academic outcomes 8 years later, controlling for potential confounders, using Odds Ratios (OR) in logistic models and β scores in linear models. A first set of models was systematically adjusted for low family income, age and gender. A second set of models was systematically adjusted for low family income, age, gender, and school difficulties prior to baseline. To determine whether to consider age in a qualitative or in a continuous fashion, we tested the log-linearity hypothesis for each outcome. Age was then considered either continuously or as a dummy variable. To select predictors to be included in the models, we estimated bivariate relationships between independent and dependent variables (Wald χ^2 /two-tailed analyses). Variables with $p < 0.25$ were subsequently entered into the initial models. Backwards selection (variables deleted when $p > 0.05$) with control for confounding factors was then conducted. Finally, we tested relevant interactions between Hyperactivity-Inattention symptoms and independent variables kept in the final model. Multicollinearity diagnostics were tested using the criteria of Belsley and colleagues (Belsley et al. 1980). The Hosmer and Lemeshow goodness-of-fit statistic was used to estimate the goodness-of-fit of each logistic model (Hosmer & Lemeshow, 2000). The model fit of linear models was assessed through graphical examination of residuals. Owing to missing data in the outcomes, we performed sensitivity analyses for the logistic models (Rubin, 1987) in order to test the robustness of the findings when applicable (i.e. Hyperactivity-inattention symptoms significantly related to the outcome). Sensitivity analyses included multiple imputation models (number of imputations=10) under missing at random (MAR) ($\delta = 0$) and not missing at random (NMAR) ($\delta = \pm \log(2)$) non-response mechanisms. Statistical significance was

determined with an alpha level of 0.05. All calculations were carried out using the SAS program version 9.1.

Results

At follow-up the sample included 1264 participants aged on average 19.3 years (range: 12.3-25.9). The descriptive socio-demographic information for the sample is contained in Table 2. Table 3 provides educational and academic outcomes by level of Hyperactivity-inattention symptoms. Academic performances were systematically lower in the group with high Hyperactivity-inattention symptoms. Grade retention was higher in the group with high Hyperactivity-inattention symptoms. Regarding situation of the youth at follow-up, hyperactive-inattentive participants were more often in technical or professional training and less often in college or university than youths with no history of such symptoms. Among participants over 18, a high level of Hyperactivity-inattention symptoms was associated with failure in secondary school graduation exam and educational underachievement.

Table 4 shows the results of regression analyses for grade retention. Model 1 was significant (Wald $\chi^2=176.71$; $p<0.0001$) and the fit was good ($p=0.99$). Model 2 was significant (Wald $\chi^2=182.92$; $p<0.0001$) and the fit was good ($p=0.95$). Anxious/depressed symptoms, oppositional defiant disorder symptoms, parental marital status, and parental psychopathology were initially entered into the model and then were removed from backwards selection. The interaction terms Hyperactivity-inattention symptoms x Conduct disorder symptoms, Hyperactivity-inattention symptoms x Low familial income, Hyperactivity-inattention symptoms x Age, and Hyperactivity-inattention symptoms x Gender were not statistically significant. Hyperactivity-inattention symptoms and Conduct disorder symptoms were significantly related to grade retention. When we restricted analyses to youths over 18 at follow-up, results were similar to what was found in the whole sample before [Hyperactivity-inattention: OR=3.12 (1.75-5.58), Conduct disorder: OR=2.14 (1.05-4.35)]

and after adjustment on school difficulties previous to baseline [Hyperactivity-inattention: OR=2.65 (1.46-4.80), Conduct disorder: 2.01 (0.99-4.14)].

Table 5 provides the results of regression models of failure to graduate from secondary school among youths over 18 at follow-up. Model 1 was significant (Wald $\chi^2=127.11$; $p<0.0001$) and the fit was good ($p=0.68$). Model 2 was significant (Wald $\chi^2=135.69$; $p<0.0001$) and the fit was good ($p=0.13$). Anxious/depressed symptoms and Parental marital status were initially entered into the model, and then removed from backwards selection. The interaction terms Hyperactivity-inattention symptoms x Conduct disorder symptoms, Hyperactivity-inattention symptoms x Low familial income, Hyperactivity-inattention symptoms x Age, and Hyperactivity-inattention symptoms x Gender were not statistically significant. Hyperactivity-inattention symptoms, Conduct disorder symptoms, and Low familial income were significantly related to failure in secondary school graduation.

Table 6 gives the results of regression analyses for educational underachievement in youths over 18 at follow-up. Model 1 was significant (Wald $\chi^2=92.88$; $p<0.0001$) and the fit was good ($p=0.47$). Model 2 was significant (Wald $\chi^2=105.39$; $p<0.0001$) and the fit was good ($p=0.36$). Anxious/depressed symptoms and Oppositional defiant disorder symptoms were initially entered into the model, and then removed from backwards selection. The interaction terms Hyperactivity-inattention symptoms x Conduct disorder symptoms, Hyperactivity-inattention symptoms x Low familial income, Hyperactivity-inattention symptoms x Age, and Hyperactivity-inattention symptoms x Gender were not statistically significant. Hyperactivity-inattention symptoms, Conduct disorder symptoms, and Low familial income were significantly related to educational underachievement.

Table 7 shows the results of multiple linear regression models of global academic performance. Model 1 (Global F=33.49; $p<0.0001$; $r^2=0.1226$) and model 2 (Global F=37.73; $p<0.0001$; $r^2=0.1619$) were significant. Graphical examination of residuals indicated that the hypotheses of normality and homoscedasticity were acceptable. Anxious/depressed symptoms

and Oppositional defiant disorder symptoms were significantly negatively associated to global academic performance in the univariate models but were no longer statistically related to the outcome in the adjusted models. In the final models, standardized β of Hyperactivity-inattention symptoms, Conduct disorder symptoms, and Low family outcome were significantly negatively related to global academic performance. When we restricted analyses to youths over 18 at follow-up, results were similar to what was found in the whole sample before [Hyperactivity-inattention: $\beta=-1.12$, $p<0.0001$; Conduct disorder: $\beta=-1.36$, $p<0.0001$] and after adjustment on school difficulties previous to baseline [Hyperactivity-inattention: $\beta=-0.85$, $p<0.0001$; Conduct disorder: $\beta=-1.02$, $p<0.0001$].

All final predictive models were without multicollinearity (all condition index numbers were lower than 20).

The risk estimates hardly changed with sensitivity analyses. Hyperactivity-inattention symptoms still predicted negative academic outcomes under MAR assumptions, before (grade retention, $p<0.0001$; failure in secondary school graduation exam, $p=0.0016$; educational underachievement, $p<0.0001$) and after considering school difficulties prior to baseline (grade retention, $p<0.0001$; failure in secondary school graduation exam, $p=0.0416$; educational underachievement, $p=0.0002$). Hyperactivity-inattention symptoms remained a predictor of negative academic outcomes under NMAR assumptions before (grade retention, $p<0.0001$; failure in secondary school graduation exam, $p=0.0011$; educational underachievement, $p<0.0001$) and after considering school difficulties prior to baseline (grade retention, $p<0.0001$; failure in secondary school graduation exam, $p=0.0488$; educational underachievement, $p=0.0006$).

Discussion

The initial aim of this study was to replicate the finding of a positive link between hyperactivity-inattention symptoms in childhood and subsequent academic underachievement

in young adulthood. We sought to replicate and extend this finding to a large French population-based sample by using a longitudinal design and limiting the spurious logical bias of circularity. Our results corroborate previous research findings showing a significant relationship between ADHD and poor academic achievement (Loe & Feldman). We found evidence of a positive and sizable association between childhood and adolescent hyperactivity-inattention symptoms and negative academic outcomes eight years later. Children with high levels of hyperactivity-inattention symptoms were over two to three times more likely than those with low levels of symptoms to display negative academic outcomes. This was a robust and consistent pattern of association throughout a large series of measures of underachievement (i.e. grade retention, failure in secondary graduation exam, lower diploma achievement, and lower performances in academic subjects). Interestingly, this association was independent from other predictors (particularly conduct disorder symptoms and low socio-economic status) but also remained present after considering school difficulties prior to baseline. This is a methodological strength of our study since it affords inference of causal precedence of risk factors on academic outcomes.

Conduct disorder symptoms accounted for the risk of poor academic achievement in bivariate analysis and after controlling for other risk factors. Our data provide evidence for a link between CD and academic underachievement beyond ADHD. CD core symptoms such as serious violations of rules could lead to school failure through non compliance to basic social and academic rules, truancy from school, and repeated exclusions. Other potential causal mechanisms between CD and poor academic performance could be found in the correlates of CD such as a subaverage verbal intelligence, substance use disorders, and environmental risk factors (Moffit & Lynam, 1994; Armstrong & Costello, 2002). Our finding of a link between CD and academic underachievement is consistent with some previous studies (Hinshaw, 1992) but discrepant with other research reports suggesting that after adjustment for ADHD, CD is no longer a predictor of poor academic outcomes (Fergusson & Horwood, 1995,

Rappoport et al. 1999). The latter surveys argued that CD is unrelated to academic underachievement except through its correlation with ADHD. Our results do not support this view. In his review, Hinshaw (1992) suggested that only adolescent and not childhood antisocial behaviour and delinquency could be related to academic failure. A possible explanation for the discrepant results could lie in the age range considered, since our sample was older than negative studies samples. Finally, both externalizing disorders independently contributed to heighten the risk of academic underachievement. This finding should be examined in the French context of the study since a controversy remains in France regarding the validity of these two disorders.

Hypotheses on causal mechanisms for the association between ADHD and academic underachievement have already been proposed. It has been posited that ADHD could be related to subsequent poor scholastic achievement through a dual pathway involving behavioural and cognitive mechanisms (Barry et al. 2002; Mash & Barkley, 2003; Raggi & Chronis, 2006; Rappoport et al. 1999). First, and most importantly, ADHD core symptoms of poor concentration, inattention, high distractibility, hyperactivity, impulsivity and motivational deficits appear to play a substantial and direct role in the development of school and academic underachievement. The behavioural core symptoms of ADHD might lead to classroom difficulties through failure to listen to instructions, inability to remember to complete school work, frequent shifting around, excessive verbal and motor activity, and failure to inhibit responses. Interestingly, the negative impact of ADHD core symptoms on academic functioning seems to be independent of executive functioning deficits. Second, the cognitive pathway might involve executive functioning deficits such as inabilities in delay response, working memory, and self-regulation of behaviours. These mechanisms could contribute to our findings, but we could not test them in our data.

It should be underlined that anxious/depressed symptoms and oppositional defiant disorder symptoms did not confer a higher risk for negative academic outcomes in the

adjusted models. Considering anxious/depressed symptoms, this result is consistent with previous research showing that a link between early depression and later educational underachievement reflected the effect of confounding factors (Fergusson & Woodward, 2002). Regarding oppositional defiant disorder little is known about its link with academic achievement, although the bivariate relationship may be overlooked by the association with conduct disorder symptoms.

Parental psychopathology was not a predictor of subsequent academic failure. This might be due to the weakness of our construct of parental psychopathology. It may also correspond to a real absence of association. Indeed a recent survey suggested that adult children of depressed parents do not present a higher risk of low academic attainment (Timko et al. 2008).

The study has some methodological limitations. First, attrition was high in this longitudinal data set. However, comparisons between eligible youths and study sample youths in 1991, and comparisons between participants and non-participants in 1999, did not reveal significant baseline differences between participants and non-participants, which lowers the possibility of systematic bias. Hence, our finding of an association between symptoms of hyperactivity/inattention and poor academic outcomes is likely to apply to other community-based populations. Second, participants were recruited among employees of a large state-owned company, which led to the under-representation of individuals with a low socio-economic status in our sample. Since families with a higher socio-economic status were more likely to participate at follow-up, our study represents a rather privileged population. As a result, in other, more varied populations, associations between symptoms of hyperactivity/inattention and academic achievement may be stronger than we report. Third, a measurement bias might have arisen from the use of self-reported questionnaires. However, self-reporting is known to involve less desirability bias than face-to-face questionnaires (Tourangeau & Yan, 2007), implying that such bias is likely to be negligible. Fourth, we used

CBCL scores to obtain proxy DSM diagnoses. Consequently we had no formal diagnosis of ADHD since symptom duration and associated impaired functioning could not be considered through the empirically-based and DSM-oriented scales. However, DSM-oriented scales have shown high levels of validity in terms of significant associations with DSM clinical diagnoses (Achenbach et al 2003). Particularly for CD and ODD, DSM-oriented scales have shown a good level of predictive power of DSM-IV diagnoses (Krol et al. 2006) showing respectively for CD/ODD problems the following figures: positive predictive power (0.80/0.58), negative predictive power (0.97/0.64), sensitivity (0.88/0.55), specificity (0.86/0.86), coefficient phi (0.64/0.42). In addition, this measure of hyperactive-inattention symptomatology allowed us to avoid, at least partially, a circularity bias (by dropping the item “poor school work”), which was a strength of our study. Nevertheless, it must be acknowledged that our study, as any study that investigates the association between ADHD and school performance, is subject to residual circularity. Indeed, the clinical definition of ADHD symptoms includes concentration problems, which are typically appreciated in school situations and often reported by teachers to parents. Hence, a reported concentration problem might directly reflect poor school performance. However, poor concentration is per se an important causal precedence of risk factor on academic outcomes, especially since hyperactivity-inattention symptoms are generally present in preschool years. Thus it cannot be entirely excluded that GAZEL Youth study participants with high levels of symptoms of hyperactivity/inattention had some school-related difficulties prior to baseline. Fifth, we could not consider ADHD subtypes (i.e. inattentive, hyperactive/impulsive or combined), which precludes our ability to explore symptom profiles specifically related to academic outcomes. Sixth, there was a slightly higher female ratio in the follow-up participants. Since females are known to exhibit more often the inattentive ADHD subtype, this could have introduced a potential bias. However, we controlled for gender in the statistical analyses. Finally, we controlled for environmental risk factors (i.e. SES, parental psychopathology, and parental marital status) and child comorbid

psychopathology (i.e. conduct disorder symptoms, oppositional defiant disorder symptoms, and anxious/depressed symptoms). However, other factors such as IQ levels, learning disability, executive functioning deficits, bipolar disorder status, adult ADHD status, treatment status, and genetic or biological factors, which might also play a confounding role, were not considered in the present study. Such factors should be controlled for in future studies.

Caution is required regarding the external validity of the results, especially because our sample was potentially biased towards healthier subjects. Nevertheless, owing to the consistent repeated positive link between hyperactivity-inattention symptoms and academic underachievement, and given the importance of the adverse outcomes related to low academic attainment, children with hyperactive-inattention symptoms should be identified and constitute a target for early interventions. Interestingly, stimulant medication has shown a significant effect on classroom measures of attention, cognitive tasks and academic efficiency (Carlson et al. 1991; DuPaul & Rapport, 1993; Elia et al. 1993). With regard to studies of long-term treatment of ADHD by stimulant medication, recent papers suggested a significant reduction in ADHD core symptomatology and a small effect size of stimulants on academic outcomes (Barbaresi et al. 2007, Schachar et al. 2002; Van der Oord et al. 2008). In addition, there is little research in ADHD children with respect to the effect of non-pharmacological interventions (such as school support programs, cognitive-behavioural therapy, or supportive therapy) or combined interventions (medication plus psychosocial treatment) on academic outcomes. However, preliminary findings suggest some value of academic interventions such as peer tutoring, computer-assisted instruction, task/instructional modifications, self-monitoring, strategy training, or homework-focused interventions (Raggi & Chronis, 2006). Further research is required to determine what type of intervention would benefit ADHD children at risk of academic failure.

Childhood hyperactivity-inattention symptoms are associated with academic underachievement in young adulthood. This finding may lead to better detection of ADHD and academic difficulties at school, so that adequate school support may be given and that children may be referred to health professionals. It may guide clinicians in detecting and managing interventions in children and adolescents with ADHD, especially when academic difficulties and conduct problems are present.

Acknowledgments

The authors express their thanks to EDF-GDF, especially to the Service des Etudes Médicales and the Service Général de Médecine de Contrôle, and to the “Caisse centrale d’action sociale du personnel des industries électrique et gazière”. We also wish to acknowledge the Risques Postprofessionnels – Cohortes de l’Unité mixte 687 Inserm – CNAMTS team responsible for the GAZEL data base management. The authors express their thanks to P. Goldberg from INSERM Unit 687, and to Dr Johnston from the Institute for Survey Research, Ann Arbor, MI. The GAZEL Cohort Study was funded by EDF-GDF and INSERM, and received grants from the Association de la Recherche sur le Cancer and from the Fondation de France. Funding for this study was provided by a Direction Générale de la Santé grant and a Mission Interministérielle de Lutte contre la Drogue et la Toxicomanie grant to Eric Fombonne.

Declaration of interest

In the United Kingdom, Dr Fombonne provided advice on the epidemiology and clinical aspects of autism to scientists advising parents, to vaccine manufacturers, and to several government committees between 1998 and 2001. Since 2004, Dr Fombonne has been an expert advisor to vaccine manufacturers and the US Department of Health and Social Services with regard to autism thimerosal litigation. None of his research has ever been funded by the industry.

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Table 1

CBCL subscales at baseline: items and Cronbach's α

Hyperactivity-inattention symptoms (Cronbach's α 0.73)	Conduct disorder symptoms (Cronbach's α 0.72)	Oppositional defiant disorder symptoms (Cronbach's α 0.73)	Anxious/depressed symptoms (Cronbach's α 0.77)
- Cannot concentrate	- Cruel to animals	- Argues	- Loneliness
- Daydreams	- Mean	- Disobedient at home	- Cries
- Impulsive	- Destroy others' things	- Disobedient at school	- Fears
- Cannot sit still	- Lacks guilt	- Stubborn	- Fears school
- Acts young	- Fights	- Temper	- Fears doing bad
- Confused	- Bad companions		- Must be perfect
- Nervous, highly strung or tense	- Lies, cheats		- Feels unloved
- Twitching	- Attacks		- Feels worthless
- Clumsy	- Runs away		- Nervous
- Stares blankly	- Sets fires		- Fearful
	- Steals at home		- Feels too guilty
	- Steals outside home		- Self-conscious
	- Swears		- Suspicious
	- Threatens		- Talks of suicide
	- Truant		- Sad
	- Vandalism		- Worries

Table 2
Socio-demographic features of sample (N=1264)

Variable	%	Mean	SD
<i>Gender</i>			
-Female	51%		
-Male	49%		
<i>Age at follow-up (years)</i>		19.3	3.6
<i>Familial income per capita at baseline</i>			
- < 5200 euros per year	34%		
- > = 5200 euros per year	66%		
<i>Parental marital status at baseline</i>			
- Divorced or separated or widow or single	6%		
- Married or cohabiting	94%		
<i>Youths' situation at follow-up</i>			
- Secondary school	45%		
- Technical or professional training	10%		
- College or university	24%		
- Employed	11%		
- Job seeker	4%		
- Other situation	7%		

Table 3
Educational and academic outcomes by level of hyperactivity-inattention symptoms

	HI-s \geq 90 th centile group (N=163)	HI-s<90 th centile group (N=1101)	p
<i>Performance in academic subjects, Mean (SD)</i>			
- Reading, French, or language arts	5.8 (2.9)	7.4 (2.6)	<0.0001
- Arithmetic or math	5.9 (3.0)	7.7 (2.7)	<0.0001
- Sciences	6.3 (2.6)	7.7 (2.5)	<0.0001
- Foreign languages	5.4 (3.3)	7.4 (2.8)	<0.0001
- Global results	5.9 (2.1)	7.6 (2.0)	<0.0001
<i>Grade retention</i>	72%	35%	<0.0001
<i>Youths' situation at follow-up</i>			
- Secondary school	37%	46%	0.0432
- Technical or professional training	18%	8%	0.0002
- College or university	13%	26%	0.0008
- Employed	13%	11%	0.4113
- Job seeker	8%	3%	0.0059
- Other situation	11%	6%	0.0348
<i>In older than 18, (N=762)</i>			
- Secondary school graduation exam	55%	76%	<0.0001
- Educational achievement	32%	63%	<0.0001

Performance in academic subjects: Each academic subject performance varied from 0 to 10
Educational achievement: Secondary school graduation exam in general education setting or post secondary/university diploma versus no diploma or technical/professional diploma

Table 4
 Childhood hyperactivity-inattention symptoms and other covariates: multiple logistic regression models of grade retention

Independent variables	Unadjusted OR (95% CI)	Adjusted OR (95% CI) model 1	Adjusted OR (95% CI) model 2
CBCL symptoms			
<i>Hyperactivity-inattention</i>	4.62 (3.20-6.67)***	3.58 (2.38-5.39)***	2.68 (1.76-4.10)***
<i>Anxious/depressed</i>	1.62 (1.15-2.27)**		
<i>Conduct disorder</i>	1.93 (1.38-2.70)***	1.84 (1.21-2.80)**	1.62 (1.04-2.51)*
<i>Oppositional defiant disorder</i>	1.39 (1.03-1.89)*		
Familial variables			
<i>Low income</i>	1.41 (1.11-1.80)**	1.15 (0.88-1.50)	1.16 (0.88-1.53)
<i>Parents divorced, separated, widowed or single</i>	1.71 (1.08-2.70)*		
<i>Parental psychopathology</i>	1.25 (0.90-1.73)		

Model 1 (N=1209) was adjusted on Age and Gender

Model 2 (N=1182) was adjusted on Age, Gender and School difficulties previous to baseline

***: $p < 0.001$, **: $p < 0.01$, *: $p < 0.05$

Due to the occurrence of grade retention prior to baseline in 153 subjects, we conducted further analyses in order to test the robustness of our findings:

1/ when we restricted analyses to subjects without prior grade retention at baseline, results remained significant before [Hyperactivity-inattention: OR=3.09 (1.99-4.80), Conduct disorder: 1.74 (1.11-2.74)] and after adjustment on school difficulties previous to baseline [Hyperactivity-inattention: OR=2.49 (1.58-3.94), Conduct disorder: OR=1.69 (1.07-2.68)]

2/ when we adjusted the models on grade retention prior to baseline, results remained significant before [Hyperactivity-inattention: OR=3.16 (2.05-4.86), Conduct disorder: OR=1.61 (1.03-2.52)] and after adjustment on school difficulties previous to baseline [Hyperactivity-inattention: OR=2.50 (1.60-3.90), Conduct disorder: OR=1.58 (1.00-2.48)]

Table 5
 Childhood hyperactivity-inattention symptoms and other covariates: multiple logistic regression models of failure in secondary school graduation exam in youths over 18 at follow-up

Independent variables	Unadjusted OR (95% CI)	Adjusted OR (95% CI) model 1	Adjusted OR (95% CI) model 2
CBCL symptoms			
<i>Hyperactivity-inattention</i>	2.63 (1.72-4.03)***	2.41 (1.43-4.05)***	1.84 (1.04-3.25)*
<i>Anxious/depressed</i>	1.36 (0.87-2.14)		
<i>Conduct disorder</i>	3.20 (1.95-5.26)***	2.90 (1.59-5.28)***	2.06 (1.09-3.91)*
<i>Oppositional defiant disorder</i>	1.26 (0.80-2.00)		
Familial variables			
<i>Low income</i>	1.17 (0.83-1.64)	1.65 (1.11-2.45)*	1.69 (1.12-2.54)*
<i>Parents divorced, separated, widowed or single</i>	1.52 (0.84-2.72)		
<i>Parental psychopathology</i>	1.11 (0.69-1.80)		

Model 1 (N=718) was adjusted on Age and Gender

Model 2 (N=714) was adjusted on Age, Gender and School difficulties previous to baseline

***: p<0.001, **: p<0.01, *: p<0.05

Table 6
 Childhood hyperactivity-inattention symptoms and other covariates: multiple logistic regression models of educational underachievement in youths over 18 at follow-up

Independent variables	Unadjusted OR (95% CI)	Adjusted OR (95% CI) model 1	Adjusted OR (95% CI) model 2
CBCL symptoms			
<i>Hyperactivity-inattention</i>	3.63 (2.33- 5.66)***	3.00 (1.84-4.89)***	2.60 (1.55-4.36)***
<i>Anxious/depressed</i>	1.42 (0.93-2.16)		
<i>Conduct disorder</i>	3.07 (1.83-5.14)***	2.37 (1.32-4.24)**	1.89 (1.02-3.51)*
<i>Oppositional defiant disorder</i>	1.96 (1.28-3.01)**		
Familial variables			
<i>Low income</i>	1.70 (1.26-2.31)***	2.16 (1.54-3.03)***	2.26 (1.60-3.21)***
<i>Parents divorced, separated, widowed or single</i>	1.34 (0.77-2.33)		
<i>Parental psychopathology</i>	1.16 (0.75-1.79)		

Model 1 (N=718) was adjusted on Age and Gender

Model 2 (N=714) was adjusted on Age, Gender and School difficulties previous to baseline

***: p<0.001, **: p<0.01, *: p<0.05

Table 7
 Childhood hyperactivity-inattention symptoms and other covariates: multiple linear regression models of global academic performance in youths

	Unadjusted β (SD)	T Value	Model 1 β (SD)	T Value	Model 2 β (SD)	T Value
CBCL symptoms						
<i>Hyperactivity-inattention</i>	-1.70 (0.17)	-9.81***	-1.30 (0.18)	-7.19***	-0.91 (0.18)	-4.95***
<i>Anxious/depressed</i>	-0.79 (0.18)	-4.32***				
<i>Conduct disorder</i>	-1.51 (0.18)	-8.50***	-1.08 (0.18)	-5.87***	-0.93 (0.18)	-5.03***
<i>Oppositional defiant disorder</i>	-0.51 (0.16)	-3.11**				
Familial variables						
<i>Low income</i>	-0.37 (0.13)	-2.89**	-0.31 (0.14)	-2.50*	-0.32 (0.12)	-2.61**
<i>Parents divorced, separated, widowed or single</i>	-0.29 (0.25)	-1.18				
<i>Parental psychopathology</i>	-0.34 (0.18)	-1.91				

Model 1 (N=1203) was adjusted on Age and Gender

Model 2 (N=1178) was adjusted on Age, Gender and School difficulties previous to baseline

***: $p < 0.001$, **: $p < 0.01$, *: $p < 0.05$