Eur Child Adolesc Psychiatry
DOI 10.1007/s00787-016-0843-4

ORIGINAL CONTRIBUTION

# Childhood trajectories of inattention-hyperactivity and academic achievement at 12 years

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Received: 7 September 2015 / Accepted: 14 March 2016
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**Abstract** Few prospective studies spanning early childhood to early adolescence have examined separately the contribution of inattention and hyperactivity to academic achievement. The aim of the present study was to investigate whether the developmental trajectories of inattention and hyperactivity symptoms during early and middle childhood are independently associated with academic achievement at age 12 years. The independent associations between inattention and hyperactivity trajectories during early and middle childhood and academic performance at age 12 years were examined in a population-based longitudinal birth cohort ($n = 2120$). In adjusted analyses, high early childhood inattention trajectories were associated with teacher-rated academic performance in reading, writing and mathematics and with government exam score in writing. High and moderate inattention trajectories during middle childhood predicted lower performance on both teacher-rated academic performance and government exam scores in reading, writing, and mathematics. Hyperactivity was not a consistent predictor of educational outcomes. Childhood inattention symptoms rather than hyperactivity carry risk of poor educational outcomes at age 12 years. Children with high levels of inattention can be identified during the preschool years. Prevention programs supporting the development of attentional capacities and executive functions could help reduce the negative consequences of inattention.

**Keywords** Academic achievement · Inattention · Hyperactivity · Early childhood · Middle childhood

## Introduction

Academic underachievement is associated with lower income, unemployment, higher rates of incarceration, and poor health status in adulthood [1, 2]. Identifying early risk factors for academic underachievement is crucial for the design of effective prevention programs. Among known risk factors, the role of attention deficit hyperactivity disorder (ADHD) and educational outcomes is well documented [3, 4]. High levels of inattention and hyperactivity in school-aged children are associated with poor grades in reading and math as well as with increased grade retention and low educational attainment [3, 4]. In addition, several prospective studies have provided evidence to support the association between ADHD symptoms/diagnosis and later academic achievement [5]. However, only four prospective studies have attempted to distinguish the effects of inattention from those of hyperactivity in the prediction of academic achievement. Lee and Hinshaw [6] followed 6–13-year-old girls diagnosed

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Published online: 26 March 2016

with ADHD and found that only inattention symptoms predicted academic achievement 5 years later. Massetti et al. [7] reported that among young children diagnosed with ADHD, only the inattentive subtype of ADHD symptoms predicted academic achievement 8 years later. Pingault et al. [8] showed in a population-based cohort that inattention during elementary school predicted lower levels of high school graduation by early adulthood (22–23 years of age), whereas hyperactivity did not. Sayal et al. [9] found similar results in a population-based sample of 7-year-old children showing that inattention was a stronger predictor of academic difficulties at age 16 years than hyperactivity. Finally, Washbrook et al. [13], without distinguishing between inattention and hyperactivity, demonstrated in a large community-based birth cohort that ADHD symptoms in early childhood (3 years) were associated with worse academic outcomes at age 16 years. In sum, extant research suggests that inattention may be more important than hyperactivity in the prediction of poor academic achievement. However, no study to date has examined the independent role of inattention and hyperactivity symptoms during early childhood in the prediction of academic achievement despite recent evidence that (1) ADHD in preschoolers ranges from 2 to 7.9 % [12] with an increase in diagnoses and psychostimulant prescription, and (2) hyperactivity and inattention problems are already present and identifiable during early childhood [10, 11]. Therefore, the respective roles of inattention and hyperactivity symptoms during early childhood remain unclear.

Moreover, few prospective studies have controlled for a range of key potential confounders factors including the sex of the child, cognitive abilities, socioeconomic status, and psychiatric comorbidity [5]. The inclusion of these confounders is important given their association with both ADHD symptoms and educational outcomes [14, 15]. The presence of comorbid disorders may also have an influence on the association between ADHD symptoms and academic achievement [16–18]. For instance, physical aggression [19] and opposition [20, 21] have been associated with hyperactivity symptoms whereas anxiety/depressive symptoms have been associated with inattention symptoms [22, 23].To address these issues, we used a large community-based birth cohort to investigate whether early and middle childhood inattention and hyperactivity symptoms were independently associated with academic achievement at the end of elementary school (age 12 years). We hypothesized that inattention and hyperactivity symptoms would predict academic achievement even after the inclusion of meaningful confounding variables and that inattention symptoms would be a better predictor than hyperactivity symptoms.

## Method

### Participants

Data from the Quebec Longitudinal Study of Child Development (QLSCD) was used. Through birth registries, the QLSCD selected 2120 singleton newborns representative of the Quebec (Canada) newborns between 1997 and 1998 [24]. Participants were assessed 11 times from 5 months to 12 years. Ethics approval and written informed parental consent were obtained at each assessment. Mother ratings of inattention and hyperactivity symptoms were obtained from 1.5 to 5 years. Teacher ratings of inattention and hyperactivity symptoms were obtained at 6, 7, 8, and 10 years. Sample sizes vary thereafter for specific outcomes. The Quebec Statistics Institute (QSI, Quebec, Canada) collected data from official Quebec government reading ($n = 980$), writing ($n = 1040$), and mathematics ($n = 1015$) exams at age 12 years. In addition, teachers rated academic performance in French ($n = 889$) and mathematics ($n = 726$) at age 12 years (Fig. 1). Additional information regarding attrition for the 2120 participants followed longitudinally is presented (Table 1, 2).

### Measures

*Predictor variables*

Early and middle childhood hyperactivity and inattention symptoms were assessed using the childhood behavior questionnaire [25]. The questionnaire includes items from the Canadian National Longitudinal Study of Children and Youth [14], the Child Behavior Checklist [26], the Ontario Child Health Study Scales [27], and the Childhood Behavior Questionnaire [25]. The instrument has been shown to have good validity [28, 29]. It was used in several studies of large sample cohorts that documented its predictive validity on ADHD and ADHD medical use among adolescents [30, 31]. Furthermore, previous studies have showed that the measure was sensitive to change over time as one or two groups of children exhibited declining levels during the elementary school [8, 32]. Mothers and teachers were asked to rate the child on a frequency scale indicating whether the child never (0), sometimes (1), or often (2) exhibits hyperactivity and inattention symptoms in the past 12 months. We have five repeated mother ratings during the early childhood period (1.5, 2.5, 3.5, 4.5, 5 years) and four teacher ratings during middle childhood (6, 7, 8, and 10 years). The following dimensions were measured with the same items for mother and teachers. Five items were used to assess hyperactivity: "can't sit still, is restless or hyperactive," "fidgets," "is impulsive, acts without

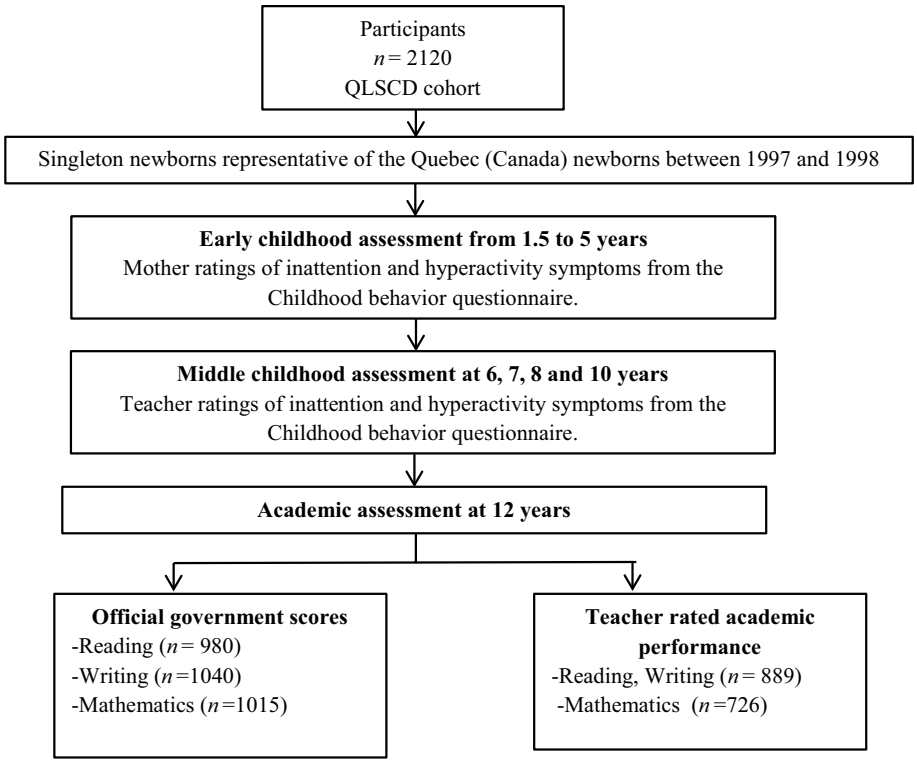


**Fig. 1** Description of the study design

**Table 1** Characteristics of participants and non-participants for teacher-rated academic performance

| | Participants $n = 930$ | Non participants $n = 1190$ | Effect sizes Cohen's *D* | *p* values |
|---|---|---|---|---|
| Male gender (%) | 428 (39.63) | 652 (60.37) | 0.09[a] | <0.001 |
| Female gender (%) | 502 (48.27) | 538 (51.730) | 0.08 | <0.001 |
| Peabody Picture Vocabulary Test (SD) | 68.15 (18.80) | 65.59 (19.04) | 0.13 | 0.037 |
| Number Knowledge Test (SD) | 9.85 (4.13) | 9.30 (4.05) | 0.13 | 0.034 |
| Opposition, childhood behavior questionnaire (SD) | 1.73 (0.31) | 1.70 (0.31) | 0.09 | 0.035 |
| Aggression, childhood behavior questionnaire (SD) | 1.41 (0.37) | 1.38 (0.35) | 0.08 | 0.084 |
| Anxiety/depression, childhood behavior questionnaire (SD) | 1.28 (0.18) | 1.27 (0.19) | 0.07 | 0.109 |

[a] Phi-coefficient was used for male and female gender

**Table 2** Characteristics of participants and non-participants for official academic achievement scores

| | Participants $n = 1173$ | Non participants $n = 947$ | Effect sizes Cohen's *d* | *p* values |
|---|---|---|---|---|
| Male gender (%) | 559 (51.76) | 521 (48.24) | 0.07[a] | <0.001 |
| Female gender (%) | 614 (59.04) | 426 (40.96) | 0.07 | <0.001 |
| Peabody Picture vocabulary Test (SD) | 68.44 (17.70) | 64.02 (21.02) | 0.23 | 0.001 |
| Number Knowledge Test (SD) | 9.89 (3.94) | 9.03 (4.36) | 0.21 | 0.003 |
| Opposition, childhood behavior questionnaire (SD) | 1.72 (0.31) | 1.70 (0.31) | 0.05 | 0.286 |
| Aggression, childhood behavior questionnaire (SD) | 1.39 (0.35) | 1.40 (0.37) | 0.01 | 0.811 |
| Anxiety/depression, childhood behavior questionnaire (SD) | 1.28 (0.18) | 1.25 (0.19) | 0.13 | 0.002 |

[a] Phi-coefficient was used for male and female gender

thinking," "has difficulty waiting for his or her turn in games," and "cannot settle down to do anything for more than a few moments."(Cronbach's alpha for the mother ratings: 0.73, Cronbach's alpha for the teacher ratings: 0.89). Three items were used to assess inattention: "cannot concentrate, cannot pay attention for long," "is easily distracted, has trouble sticking to any activity," and "is inattentive."(Cronbach's alpha for the mother ratings: 0.80, Cronbach's alpha for teacher ratings: 0.90).

### Academic outcomes variables

Academic performance was assessed at age 12 years using (1) results on province-wide ministerial exams for reading, writing, and mathematics and (2) teacher report of the participants' academic average in reading, writing, and mathematics.

1. Participants' results on province-wide ministerial exams. Quebec student must write mandatory government exams at the end of elementary to be admissible to enter high school. Teachers from various Quebec school boards as well as education consultants were involved in the development of this ministry examination [33, 34]. The mathematics examination is designed to evaluate students' capacity to (1) solve a mathematical problem applied to a real life situation and (2) reason using mathematical concepts and processes [35]. The writing test is designed to assess the capacity to write a variety of texts and the reading test to evaluate the capacity to read and understand a variety of texts [36]. The data were marked by a team of 15 people selected according to the criteria established by the Ministry of Education, Recreation and Sports (MELS) [35, 36] under the supervision of the QSI. For all tests, inter-rater reliability tests were performed on a subset of copies to ensure the quality of the correction [35, 36]. Achievement was evaluated with an overall score out of 100 for reading comprehension (6–100), writing (32–100), and mathematics exams (22–100).
2. Teacher reports of the participants' academic performance. French teacher reported the academic average of the year of the participants in reading and writing while mathematics teacher reported the academic average of the year of the participants in mathematics.

### Confounder variables

Analyses were adjusted for factors that potentially confound the relationship between hyperactivity, inattention symptoms, and academic achievement. Initial individual-level confounding variables were the gender of the child (coded as 0 for boys and 1 for girls) and cognitive abilities assessed at the age of 5 years using the Peabody Picture Vocabulary test revised [37] and the Number Knowledge Test [38]. The Peabody Picture Vocabulary test (PPVT) assesses receptive vocabulary and is highly correlated with other measures of intelligence [39]. The Number Knowledge Task (NKT) assesses arithmetic cognitive abilities [38] and the development and understanding of number concepts.

Parental sociodemographic indicators were collected from a family socioeconomic adversity index [40] which is derived from five sources: the level of education of (1) the mother and (2) of the spouse/partner, the prestige of (3) the mother's occupation and (4) that of the spouse/partner, and (5) household income [41].

Anxiety/depressive symptoms, physical aggression, and opposition were assessed during early childhood (1.5–5 years old) using mother rating on the childhood behavior questionnaire [25]. Each item was scored from 1 to 3, depending on how frequently the child manifested the behavior. The score for each dimension was averaged across the 5 years of assessment. The following seven item assessed anxiety/depressive symptoms: (1) is nervous, highstrung or tense; (2) is too fearful or anxious; (3) is worried; (4) appeared sad or depressed; (5) is not happy as other children; (6) has trouble enjoying himself; (7) cries a lot (mean score = 1.27 [SD = 0.18] Cronbach's alpha: 0.82). Four items were used to assess opposition: (1) opposition defiant or refused to comply with adults' requests or rules; (2) does not seem to feel guilty after misbehaving; (3) punishment did not change his/her behaviour; (4) had temper tantrums or hot temper (mean score = 1.71[0.31]; Cronbach's alpha: 0.81). Three items were used to assess physical aggression: (1) hits, bites, kicks; (2) fights with other children; (3) bullies other children (mean score = 1.39 [0.36]; Cronbach's alpha: 0.84).

### Analysis

The analyses were performed in two steps. First, we estimated trajectories of hyperactivity and inattention symptoms from 1.5 to 10 years. This estimation was conducted through group-based trajectory modeling using semiparametric mixture models with censored-normal distributions [42]. Models were estimated separately for early (1.5–5 years) and middle childhood (6–10 years) to be in line with the distinct developmental stages corresponding to increase in autonomy and educational contexts. The method provided the capacity to (1) identify groups of boys and girls following trajectories with distinct levels of behaviors over time, (2) estimate the proportion of children in each of the identified trajectory groups, and (3) estimate the patterns of stability and variations in trajectories. The semiparametric mixture model assigns individuals

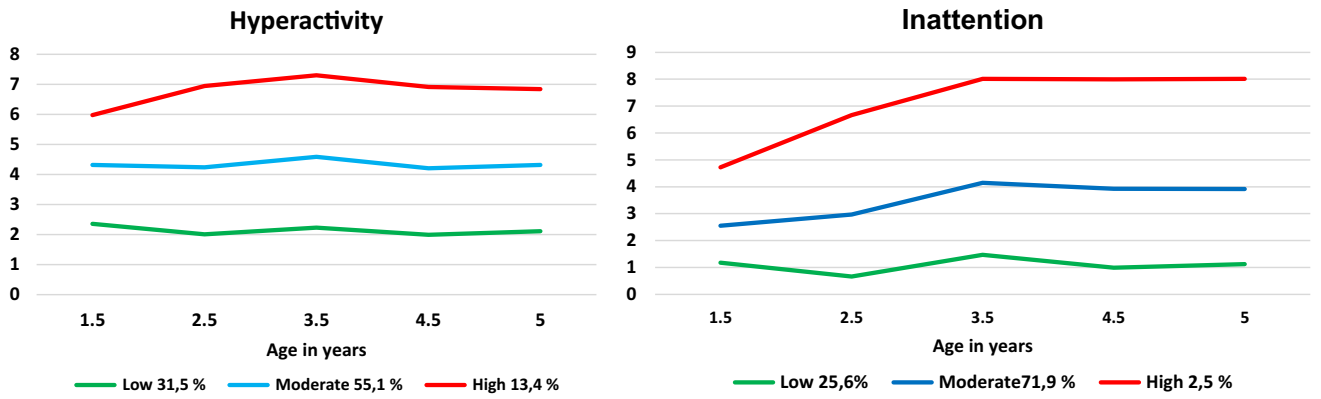


**Fig. 2** Developmental trajectories of hyperactivity and inattention during early childhood

to categories on the basis of a posterior probability rule. Resulting groups are approximations of underlying continuous processes [42, 43]. Models with 2–5 groups were estimated. The selection of the final model was based on two main criteria: (1) Statistical indexes: The model that minimized the Bayesian Information Criterion (lowest BIC [42]) and maximized entropy (i.e. the extent to which groups are well separated) and (2) the size of the trajectory groups. That is, the selected model had a sufficient proportion of children in the different groups to be usable in prediction analyses. In addition, the high trajectory group included a sufficiently small number of children to reflect an atypically elevated developmental pattern. The procedure handles missing data by assigning a subject to the trajectory that is closest to his/her available score (s).

Second, we performed multivariate linear regression analyses for each outcome. We examined the predictive link between the trajectories of hyperactivity and inattention symptoms at early childhood and middle childhood and academic performance at age 12 years controlling for confounders. In each model, the predictor and confounder variables were introduced sequentially. At step 1, we entered the predictor variable—trajectories of inattention and hyperactivity for the early childhood period (1.5–5 years). At step 2, we introduced the confounder variables measured during early childhood period (1.5–5 years). The Peabody Picture Vocabulary Test revised was included as a confounding variable for writing and reading outcomes as it measured verbal cognitive abilities. The Number Knowledge Test was use as a confounder for mathematic outcomes. At the final stage, we entered the predictor variables—trajectories of inattention and hyperactivity for middle childhood period (6–10 years).

### Attrition and missing data

Table 1 presents the characteristics of the follow-up participants and non-participants for academic average in reading, writing, and mathematics assessed by teachers. No significant difference was found on early childhood anxious/depressed symptoms and physical aggression. However, participants came from significantly higher socio-economic backgrounds, were more often female, and had higher cognitive abilities scores. Significant differences were also noted for opposition symptoms but this difference was clearly low in magnitude (Cohen $d = 0.09$). Table 2 shows the characteristics of the follow-up participants and non-participants regarding government exams scores in reading, writing, and mathematics. The same pattern of results was obtained regarding socioeconomic variables, gender, and cognitive abilities scores. Small significant differences were noted for anxiety and depression symptoms (Cohen $d = 0.13$).

## Results

### Developmental trajectories of inattention and hyperactivity during early and middle childhood

We identified a 3-group model as the best fit for individual developmental trajectories of hyperactivity and a 3-group model as the best fit for individual developmental trajectories of inattention both at early childhood and middle childhood.

Figure 2 shows the trajectory model for early childhood. The three early childhood hyperactivity trajectories were as follows: high (13.4 %), moderate (55.1 %), and low (31.5 %). The three early childhood inattention trajectories were as follows: high (2.5 %), moderate (71.9 %), and low (25.6 %). Figure 3 shows the trajectory model for middle childhood. The three middle childhood hyperactivity trajectories were as follows: high (12.8 %), moderate (44.8 %), and low (42.4 %). The three middle childhood inattention trajectories were as follows: high (17.3 %), moderate (52.1 %), and low (30.6 %).

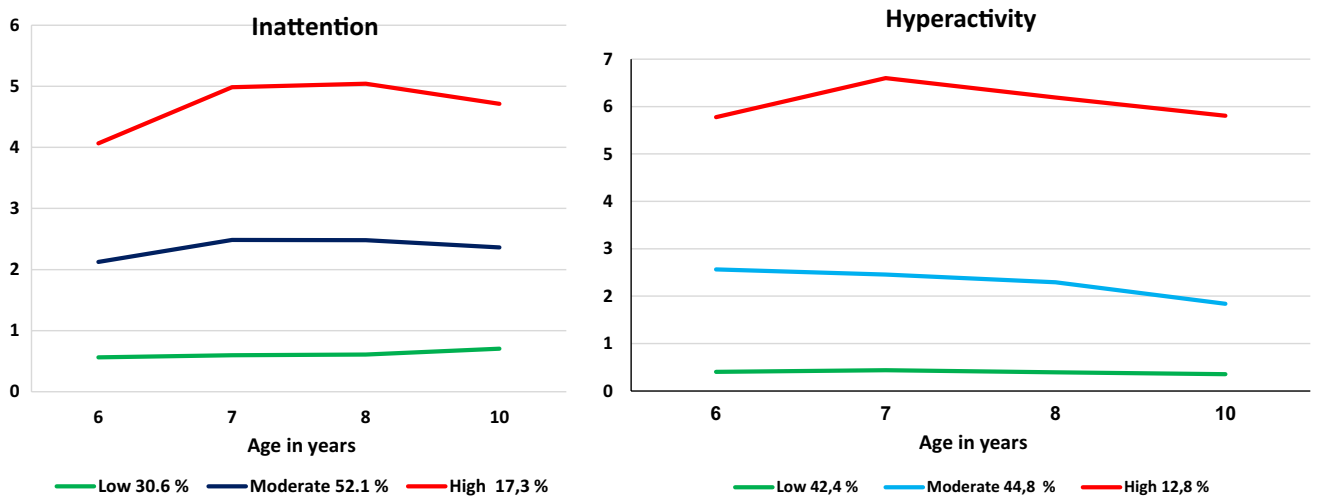


**Fig. 3** Developmental trajectories of hyperactivity and inattention during middle childhood

### Prediction of teacher-rated academic performance in reading, writing, and mathematics

Table 3 shows the results of multiple linear regression models of teacher-rated academic performance in reading, writing, and mathematics at age 12 years. After adjusting for the gender of the child and cognitive abilities, parental socioeconomic indicators, early childhood anxiety/depression, opposition, and physical aggression, the early childhood high inattention trajectory ($\beta = -0.13$ CI $-18.99$, $-4.74$; $p = 0.001$) and the middle childhood high ($\beta = -0.38$ CI $-12.03$, $-5.81$; $p = 0.001$) and moderate ($\beta = -0.22$ CI $-6.94$, $-2.90$; $p = 0.001$) inattention trajectories were significantly negatively associated with academic average in reading and writing. Hyperactivity trajectories did not make a significant contribution. Regarding the academic average in mathematics, in adjusted models (Table 4), the early childhood high inattention trajectory ($\beta = -0.12$ CI $-20.47$, $-2.06$; $p = 0.017$), the early childhood moderate hyperactivity trajectory ($\beta = -0.12$ CI $-5.46$, $-0.17$; $p = 0.037$), and the middle childhood high ($\beta = -0.29$ CI $-14.60$, $-6.20$; $p = 0.001$) and moderate ($\beta = -0.23$ CI $-7.83$, $-2.82$; $p = 0.001$) inattention trajectories made a significant contribution. The standardized coefficients for middle childhood inattention trajectories were larger than those for early childhood hyperactivity trajectory. Hyperactivity trajectories during middle childhood were not a significant predictor.

### Prediction of government exam scores in reading, writing, and mathematics

Table 4 presents the results of multiple linear regression models of government exams scores in reading, writing, and mathematics at age 12 years. Only the middle childhood moderate ($\beta = -0.15$ CI $-7.79$, $-2.02$; $p = 0.001$) and high inattention trajectories ($\beta = -0.30$ CI $-18.44$, $-9.30$; $p = 0.001$) were significantly negatively associated with government exam score in reading after controlling for the gender of the child and cognitive abilities, parental socioeconomic indicators, early childhood anxiety/depression, opposition, and physical aggression. Regarding government exam score in writing (Table 4) in adjusted models, the early childhood high inattention trajectory ($\beta = -0.10$ CI $-20.89$, $-3.29$; $p = 0.007$), and the middle childhood high ($\beta = -0.32$ CI $-17.38$, $-9.76$; $p = 0.001$) and moderate ($\beta = -0.24$, CI $-9.63$, $-4.77$; $p = 0.001$) inattention trajectories made significant contributions. For government exam score in mathematics (Table 4), only the middle childhood high ($\beta = -0.36$ CI $-21.30$, $-11.99$; $p = 0.001$) and moderate ($\beta = -0.30$ CI $-12.64$, $-6.73$; $p = 0.001$) inattention trajectories were predictors in adjusted models. Early and middle childhood hyperactivity trajectories were not significantly associated with government exams scores.

## Discussion

This 12-year follow-up study highlights the adverse effects of childhood inattention on academic achievement in adolescence. After controlling for meaningful variables, we found that (a) inattention trajectories reported by parents during early childhood were a predictor of academic achievement reported by teachers in reading, writing, and mathematics as well as by government exams in writing. Hyperactivity trajectories during early childhood did not make additional significant

**Table 3** Multiple linear regression models to predict academic average in reading, writing and mathematics at age 12

| Variable and trajectory | Unadjusted coefficients | | Adjusted coefficients[a] | | Adjusted coefficients[b] | |
|---|---|---|---|---|---|---|
| | *Stand. B* (95CI) | *p* | *Stand. B* (95CI) | *p* | *Stand. B* (95CI) | *p* |
| Academic average in reading and writing | | | | | | |
| Early childhood inattention trajectories[c] | | | | | | |
| Moderate | 0.00 (−2.44, −2.59) | 0.953 | −0.03 (−2.92, 1.59) | 0.563 | −0.02 (−2.71, 1.58) | 0.607 |
| High | −0.13 (−20.30, −3.70) | 0.005 | −0.15 (−20.60, −5.66) | 0.001 | −0.13 (−18.99, −4.74) | 0.001 |
| Early childhood hyperactivity trajectories[c] | | | | | | |
| Moderate | −0.14 (−5.68, −0.86) | 0.008 | −0.06 (−3.54, 0.87) | 0.239 | 0.00 (−2.12, 2.17) | 0.982 |
| High | −0.13 (−9.03, −1.16) | 0.011 | 0.01 (−3.53, 4.19) | 0.867 | 0.03 (−2.62, 4.89) | 0.553 |
| Gender[d] | | | 0.26 (4.09, 7.51) | 0.001 | 0.17 (2.11, 5.56) | 0.001 |
| Family socioeconomic adversity index | | | 0.27 (3.05, 5.71) | 0.001 | 0.23 (2.53, 5.07) | 0.001 |
| Peabody Picture Vocabulary test[e] | | | 0.24 (0.09, 0.19) | 0.001 | 0.17 (0.05, 0.15) | 0.001 |
| Opposition | | | 0.03 (−2.34, 4.64) | 0.518 | −0.01 (−2.16, 4.46) | 0.497 |
| Aggression | | | 0.07 (−0.43, 4.78) | 0.102 | 0.03 (−0.44, 4.53) | 0.107 |
| Anxiety/Depression | | | 0.01 (−4.66, 5.69) | 0.844 | 0.07 (−5.56, 4.31) | 0.804 |
| Middle childhood inattention trajectories[c] | | | | | | |
| Moderate | | | | | −0.22 (−6.94, −2.90) | 0.001 |
| High | | | | | −0.38 (−12.03, −5.81) | 0.001 |
| Middle childhood hyperactivity trajectories[c] | | | | | | |
| Moderate | | | | | −0.04 (−3.01, 1.08) | 0.355 |
| High | | | | | −0.05 (−5.12, 1.50) | 0.282 |
| $R^2$ | 0.05 | | 0.28 | | 0.36 | |
| Academic average in mathematics | | | | | | |
| Early childhood inattention trajectories[c] | | | | | | |
| Moderate | 0.11 (−0.16, 5.67) | 0.064 | 0.09 (−0.44, 5.13) | 0.099 | 0.09 (−0.45, 4.90) | 0.103 |
| High | −0.14 (−24.02, −4.08) | 0.006 | −0.16 (−25.01, −6.04) | 0.001 | −0.12 (−20.47, −2.06) | 0.017 |
| Early childhood hyperactivity trajectories[c] | | | | | | |
| Moderate | −0.22 (−7.97, −2.34) | 0.001 | −0.17 (−6.79,−1.34) | 0.004 | −0.12 (−5.46, −0.17) | 0.037 |
| High | −0.13 (−9.60, −0.54) | 0.028 | −0.14 (−6.11, 3.16) | 0.007 | −0.03 (−5.67, 3.35) | 0.612 |
| Gender[d] | | | 0.09 (0.04, 4.19) | 0.046 | 0.00 (−2.02, 2.20) | 0.935 |
| Family socioeconomic adversity index | | | 0.23 (2.32, 5.50) | 0.001 | 0.20 (1.83, 4.89) | 0.001 |
| Number Knowledge test[e] | | | 0.22 (0.37, 0.90) | 0.001 | 0.13 (0.09, 0.63) | 0.008 |
| Opposition | | | −0.00 (−4.60, 3.99) | 0.888 | −0.00 (−4.19, 4.02) | 0.968 |
| Aggression | | | 0.06 (−1.20, 5.15) | 0.221 | 0.07 (−0.64, 5.45) | 0.122 |
| Anxiety/depression | | | 0.04 (−3.62, 8.28) | 0.442 | −0.00 (−6.20, 5.31) | 0.880 |
| Middle childhood inattention trajectories[c] | | | | | | |
| Moderate | | | | | −0.23 (−7.83, −2.82) | 0.001 |
| High | | | | | −0.29 (−14.60, −6.20) | 0.001 |
| Middle childhood hyperactivity trajectories[c] | | | | | | |
| Moderate | | | | | −0.02 (−3.09, 1.96) | 0.660 |
| High | | | | | −0.03 (−5.64, 2.98) | 0.544 |
| $R^2$ | 0.06 | | 0.20 | | 0.28 | |

[a] Adjusted for Gender, family socioeconomic adversity index, cognitive abilities, opposition, aggression, anxiety/depression

[b] Adjusted for gender, family socioeconomic adversity index, cognitive abilities, opposition, aggression, anxiety/depression and early childhood inattention and hyperactivity trajectories

[c] Low trajectories were used as contrasts

[d] Gender (1 = girls, 0 = boys)

[e] The Peabody Picture Vocabulary Test revised was included as a confounding variable for French outcomes and The Number Knowledge Test as a confounder for mathematic outcomes

**Table 4** Multiple linear regression models to predict academic achievement score in reading, writing and mathematics at age 12

| Variable and trajectory | Unadjusted coefficients | | Adjusted coefficients[a] | | Adjusted coefficients[b] | |
|---|---|---|---|---|---|---|
| | *Stand. B* (95CI) | *p* | *Stand. B* (95CI) | *p* | *Stand. B* (95CI) | *p* |
| Reading | | | | | | |
| Early childhood inattention trajectories[c] | | | | | | |
| Moderate | −0.00 (−3.97, 3.46) | 0.892 | 0.00 (−3.11, 3.60) | 0.887 | 0.00 (−3.15, 3.23) | 0.981 |
| High | −0.02 (−17.20, 11.43) | 0.692 | −0.01 (−15.17, 10.70) | 0.734 | −0.02 (−15.79, 8.95) | 0.587 |
| Early childhood hyperactivity trajectories[c] | | | | | | |
| Moderate | −0.11 (−7.19, −0.19) | 0.039 | −0.09 (−6.21, 0.20) | 0.066 | −0.05 (−4.58, 1.61) | 0.348 |
| High | −0.12 (−12.31, −0.92) | 0.023 | −0.01 (−6.33, 4.92) | 0.807 | −0.06 (−4.33, 6.65) | 0.156 |
| Gender[d] | | | 0.12 (1.50, 6.45) | 0.002 | 0.05 (−0.81, 4.12) | 0.187 |
| Family socioeconomic adversity index | | | 0.36 (2.97, 6.89) | 0.001 | 0.17 (2.31, 6.04) | 0.001 |
| Peabody Picture Vocabulary Test[e] | | | 0.20 (0.26, 0.40) | 0.001 | 0.30 (0.21, 0.35) | 0.001 |
| Opposition | | | 0.01 (−1.10, 9.07) | 0.124 | 0.08 (−0.50, 9.17) | 0.079 |
| Aggression | | | 0.07 (−5.32, 2.49) | 0.476 | −0.02 (−4.47, 2.10) | 0.698 |
| Anxiety/depression | | | −0.03 (−6.04, 8.70) | 0.722 | −0.02 (−9.02, 5.14) | 0.590 |
| Middle childhood inattention trajectories[c] | | | | | | |
| Moderate | | | | | −0.15 (−7.79, −2.02) | 0.001 |
| High | | | | | −0.30 (−18.44, −9.30) | 0.001 |
| Middle childhood hyperactivity trajectories[c] | | | | | | |
| Moderate | | | | | −0.02 (−3.50, 2.25) | 0.669 |
| High | | | | | −0.07 (−8.10, 1.18) | 0.132 |
| $R^2$ | 0.02 | | 0.25 | | 0.33 | |
| Writing | | | | | | |
| Early childhood inattention trajectories[c] | | | | | | |
| Moderate | −0.05 (−5.02, 1.44) | 0.277 | −0.04 (−3.98, 1.61) | 0.406 | −0.05 (−4.30, 1.03) | 0.228 |
| High | −0.10 (−22.72, −1.08) | 0.031 | −0.10 (−21.58, −3.09) | 0.009 | −0.10 (−20.89, −3.29) | 0.007 |
| Early childhood hyperactivity trajectories[c] | | | | | | |
| Moderate | −0.07 (−5.23, 0.88) | 0.162 | −0.02 (−3.17, 2.25) | 0.740 | 0.02 (−1.96, 3.27) | 0.622 |
| High | −0.14 (−12.02, −2.06) | 0.006 | −0.01 (−4.98, 4.40) | 0.904 | 0.01 (−4.22, 4.92) | 0.881 |
| Gender[d] | | | 0.27 (5.89, 10.02) | 0.001 | 0.22 (4.43, 8.56) | 0.001 |
| Family socioeconomic adversity index | | | 0.27 (4.35, 7.57) | 0.001 | 0.24 (3.70, 6.79) | 0.001 |
| Peabody picture Vocabulary Test[e] | | | 0.30 (0.19, 0.31) | 0.001 | 0.25 (0.15, 0.26) | 0.001 |
| Opposition | | | 0.01 (−3.58, 4.76) | 0.781 | 0.02 (−2.87, 5.08) | 0.585 |
| Aggression | | | 0.01 (−2.61, 3.80) | 0.716 | 0.03 (−1.96, 4.19) | 0.477 |
| Anxiety/depression | | | 0.07 (−0.15, 11.75) | 0.056 | 0.04 (−2.14, 9.27) | 0.220 |
| Middle childhood inattention trajectories[c] | | | | | | |
| Moderate | | | | | −0.24 (−9.63, −4.77) | 0.001 |
| High | | | | | −0.32 (−17.38, −9.76) | 0.001 |
| Middle childhood hyperactivity trajectories[c] | | | | | | |
| Moderate | | | | | 0.05 (−0.83, 3.93) | 0.200 |
| High | | | | | 0.04 (−2.02, 6.23) | 0.317 |
| $R^2$ | 0.04 | | 0.32 | | 0.39 | |
| Mathematics | | | | | | |
| Early chilhood inattention trajectories[c] | | | | | | |
| Moderate | 0.03 (−2.59, 4.34) | 0.619 | 0.05 (−1.64, 5.02) | 0.320 | 0.04 (−1.84, 4.46) | 0.414 |
| High | −0.08 (−22.13, 1.62) | 0.090 | −0.09 (−22.20, 0.60) | 0.063 | −0.07 (−19.21, 2.34) | 0.125 |
| Early childhood hyperactivity trajectories[c] | | | | | | |
| Moderate | −0.09 (−6.09, 0.45) | 0.091 | −0.07 (−5.51, 0.92) | 0.161 | −0.03 (−3.96, 2.18) | 0.571 |
| High | −0.08 (−10.09, 1.03) | 0.110 | −0.03 (−7.43, 4.19) | 0.584 | −0.02 (−6.48, 4.70) | 0.755 |

**Table 4** continued

| Variable and trajectory | Unadjusted coefficients | | Adjusted coefficients[a] | | Adjusted coefficients[b] | |
|---|---|---|---|---|---|---|
| | *Stand. B* (95CI) | *p* | *Stand. B* (95CI) | *p* | *Stand. B* (95CI) | *p* |
| Gender[d] | | | 0.01 (−2.23, 2.82) | 0.818 | −0.06 (−4.34, 0.64) | 0.144 |
| Family socioeconomic adversity index | | | 0.28 (4.53, 8.38) | 0.001 | 0.23 (3.63, 7.28) | 0.001 |
| Number Knowledge Test[e] | | | 0.16 (0.34, 1.01) | 0.001 | 0.09 (0.06, 0.70) | 0.020 |
| Opposition | | | 0.02 (−4.12, 6.32) | 0.679 | 0.03 (−3.29, 6.59) | 0.513 |
| Aggression | | | 0.02 (−2.98, 5.13) | 0.603 | 0.04 (−1.79, 5.92) | 0.293 |
| Anxiety/depression | | | 0.00 (−7.45, 7.71) | 0.973 | −0.03 (−9.49, 4.89) | 0.530 |
| Middle childhood inattention trajectories[c] | | | | | | |
| Moderate | | | | | −0.30 (−12.64, −6.73) | 0.001 |
| High | | | | | −0.36 (−21.30, −11.99) | 0.001 |
| Middle childhood hyperactivity trajectories[e] | | | | | | |
| Moderate | | | | | 0.02 (−2.19, 3.67) | 0.621 |
| High | | | | | 0.03 (−3.25, 6.76) | 0.491 |
| $R^2$ | 0.02 | | 0.14 | | 0.24 | |

[a] Adjusted for Gender, family socioeconomic adversity index, cognitive abilities, opposition, aggression, anxiety/depression

[b] Adjusted for Gender, family socioeconomic adversity index, cognitive abilities, opposition, aggression, anxiety/depression and early childhood inattention and hyperactivity trajectories

[c] Low trajectories were used as contrasts

[d] Gender (1=girls, 0=boys)

[e] The Peabody picture Vocabulary Test revised was included as a confounding variable for reading and writing academic achievement scores and the Number Knowledge Test as a confounder for mathematic academic achievement score

contributions, except for teacher-rated academic performance in mathematics, where the association was weaker than with inattention; (b) children on the moderate or high trajectories of inattention reported by teachers during middle childhood had poorer academic performance at 12 years, as reflected in both lower scores on the government exams and teacher-rated academic performance. Hyperactivity reported by teachers during middle childhood was not a significant predictor. This was a consistent pattern of association throughout a large series of measures of academic achievement. The findings add to a growing body of evidence supporting the conclusion that inattention is a stronger predictor than hyperactivity of later academic difficulties [5–9]. By highlighting that inattention problems during early childhood impact academic performance at the age of 12 years, we extend the findings from Washbrook et al. [13] who reported that hyperactivity/inattention at the age of 3 years predicted exam performance at the age of 16 years, but did not distinguish between inattention and hyperactivity. Several options may explain the negative association between inattention and later poor academic performance. The first is that early childhood inattention interferes with the acquisition of basic academic skills necessary for school success [17, 44]. The failure to develop these skills may have an impact on classroom engagement, motivation, organization, and homework completion [9]. Deficits in basic academic skills may become particularly problematic with the increase in academic demands and sustained attention during adolescence. Another explanation pertains to the finding that inattention symptoms remain stable or increase with age while hyperactivity symptoms tend to decrease [45–47]. Thus, inattention remains a more important problem than hyperactivity as children grow older, at least in terms of the prevalence of atypically high levels of these symptoms. Third, our findings might reflect the association between executive function deficits, notably working memory and inattention in predicting poor academic performance. Indeed, several studies found that the cognitive factor of working memory is implicated in academic achievement and is strongly related to inattention. Thus, it may be that working memory mediates the relationship between inattention and academic problems [48–51]. Finally, our findings also highlight that the effect sizes were larger for middle childhood inattention symptoms compared to preschool symptoms. These results might come about because early childhood is characterized by lower expectations of sustained attention than middle childhood and, therefore, there are fewer opportunities to detect high levels of inattention during this period.

### Strengths and limitations

To the best of our knowledge, this is the first study using a community sample to estimate the respective contribution of early and middle childhood inattention and hyperactivity to later academic achievement while controlling for a large array of meaningful variables. Previous longitudinal studies provided information on childhood hyperactivity and inattention symptoms, and later academic achievement but only over a limited developmental period (e.g. middle childhood to young adults [8], early childhood to adolescence [7, 13], middle childhood to adolescence [17], adolescence to adults [30] or within adolescence [6]). Inclusion of early and middle childhood assessment of hyperactivity and inattention problems enabled a better understanding of how predictors in different developmental periods work together. In addition, as hyperactivity and inattention assessments were available from mothers and teachers at yearly intervals, it was possible to identify the developmental trajectories of these mental health symptoms over a 10-year period and use them as predictors of academic achievement at the end of elementary school. Compared to a single assessment, the use of developmental trajectory analysis over a long and developmentally significant period reduces measurement error and offers a more reliable estimation of the association between hyperactivity, inattention, and academic achievement. In addition, the partial replication of the results with an independently and externally marked measure of academic achievement (standardized tests) and an ecological one (teacher-rated) provided a strong test of the consistence and robustness of the association between hyperactivity and inattention symptoms and later academic achievement [3, 52]. However, some limitations should be noted. First, as is common in longitudinal studies spanning more than a decade, we have a substantial rate of attrition. We cannot exclude that attrition may have biased the results. We note, however, that attrition may have led to an underestimation of the effects, as children with the most severe behavioral and academic problems tend to be underrepresented at the end of the study. The fact that we found several significant associations comforts us in our power to detect meaningful effects despite attrition. Second, although we controlled for the sex of the child, cognitive abilities at 5 years, aggression, opposition, anxiety/depression, and parental socioeconomic variables, other potential confounders such as learning disability, deficits in executive functions, teaching quality, and organizational setting [13] were not measured in this study. Third, the developmental trajectories for each developmental period relied on one informant, i.e. the mother for early childhood and the teacher for middle childhood period. Multiple raters may better account for the situational variation in children's behavior [53, 54]. However, parents provide the most reliable assessment of hyperactivity and inattention during early childhood [30] and teachers provide the most reliable assessment during middle childhood [55, 56]. Fourth, because teachers may tend to give higher ratings of inattention to students who have poorer academic performance, their assessment could be biased by a general negative halo effect [8]. The use of 4 years of assessment by independent teachers might have mitigated this halo effect. Finally, the instrument used includes few inattention and hyperactivity symptoms. Yet, these symptoms have proven to be predictive of a range of adolescent outcomes in numerous studies [30, 31], and our predictive results were based on eleven repeated assessments over a 10-year period.

## Conclusions

Despite these limitations, the present results clearly suggest that early and middle childhood inattention is conducive to long-term educational difficulties. Symptoms of inattention were associated with all the skills we evaluated suggesting overall scholastic difficulties. The findings highlight the importance of considering inattention during early childhood as an important predictor of later academic achievement problems. Furthermore, the findings support the suggestion made in a previous study [8] to differentiate inattention from hyperactivity and to focus on inattentive symptoms in preventive actions. It has been reported that preschool children can substantially benefit from preventive interventions targeting attention problems [57]. In addition, some studies reported that training and coaching among school-aged children and adolescent with ADHD could improve attention in school and account for more self-regulated behavior and better motivation [58–61]. However, more research is required to determine whether intervention when children are young is cost-effective in offsetting the adverse educational outcomes. In terms of practical implications, teachers and parents should be aware of the long-term adverse effect of early inattention problems on academic achievement. Teachers are a key point of contact for parents and may play an essential role in the identification of at-risk children. From a clinical perspective, as hyperactivity symptoms are more salient and better detected than inattention symptoms, parents and teachers should be encouraged and guided by early childhood educators and clinicians to be more sensitive and better able to detect attention problems during early childhood.

**Acknowledgments** The Québec Institute of Statistics and the staff of the Groupe de Recherche sur l'Inadaptation Psychosociale chez l'Enfant (GRIP) provided data collection and management. Part of the Statistical analyses was conducted by Dr. Liu under the guidance of Dr. Côté.

**Funding source** This research was supported by the Quebec's Ministry of Health; the Quebec's Health Research Fund (FRQ-S); the Québec's Culture and Society Research Fund (FRQ-SC); Canada's Social Science and Humanities Research Council (SSHRC); the Canadian Institutes for Health Research (CIHR); St-Justine Hospital's Research Center, and the University of Montréal. Dr Côté is a senior fellow of the Quebec's Health Research Fund (FRQ-S).

**Contributors' statement** Julie Salla, Dr. Salla carried out all analyses, drafted the manuscript and approved the final manuscript as submitted. Grégory Michel, Dr.Michel designed the analyses, reviewed the manuscript and approved the final manuscript as submitted. Jean Baptiste Pingault, Eric Lacourse, Stéphane Paquin, Cédric Galéra, Bruno Falissard, Drs. Pingault, Lacourse, Paquin, Galéra, Falissard reviewed the manuscript and approved the final manuscript as submitted. Michel Boivin, Dr. Boivin designed the data collection instruments, reviewed the manuscript and approved the final manuscript as submitted. Richard E. Tremblay, Dr. Tremblay conceptualized, designed the study, designed the data collection instruments, reviewed the manuscript and approved the final manuscript as submitted. Sylvana M. Côté, Dr. Côté conceptualized and designed the study, critically reviewed the analyses and the manuscript, and approved the final manuscript as submitted.

**Compliance with ethical standards**

**Financial disclosure** The authors have no financial relationships relevant to this article to disclose.

**Conflict of interest** On behalf of all authors, the corresponding author states that there is no conflict of interest.

**Integrity of research** The study has been approved by the appropriate ethics committee and therefore been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments.

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