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Associations of Attention Deficit Hyperactivity Disorder (ADHD) at School Entry with Early Academic Progress in Children Born Prematurely and Full-Term Controls

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1. INTRODUCTION

Extremely preterm/extremely low birth weight (EPT/ELBW) children (i.e., those with gestational age [GA] <28 weeks and/or birth weight <1000 g), compared to term-born, normal birth weight (NBW) children (with GA >36 weeks and birth weight >2500 g), have poorer reading, spelling, and mathematics skills (Anderson & Doyle, 2004; Grunau, Whitfield, & Fay, 2004; Simms et al., 2014; Taylor, Klein, Schluchter, & Hack, 2006). Adverse effects on achievement are evident at school entry and persist across the school-age years (Taylor et al., 2011; Grunau et al., 2004; Saigal, Hoult, Streiner, Stoskopf, & Rosenbaum, 2000). EPT/ELBW cohorts and the wider spectrum of very preterm/very low birth weight (VPT/VLBW) children (with GA <32 weeks and/or <1500 g birth weight) also have higher rates of attention deficit hyperactivity disorder (ADHD) than their NBW peers (Anderson et al., 2011; Jaekel, Wolke, & Bartmann, 2013; Johnson et al., 2016; Scott et al.,

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2012; Scott et al., 2017). According to some estimates, rates of ADHD in school-age VPT/VLBW children range from 9–11%, with somewhat higher rates of 17–20% in EPT/ELBW samples (Johnson & Marlow, 2011). This compares to population estimates of 5–7% (Murray, Robinson, & Tripp, 2017; Thomas, Sanders, Doust, Beller, & Glasziou, 2015). However, estimates vary substantially across studies of preterm children (Franz et al., 2018), with rates as high as 40% reported in studies of parent-reported ADHD (Samuelsson et al., 2017). Increased rates of ADHD in preterm compared to NBW groups are found even when excluding children with cognitive impairment (Anderson et al., 2011; Scott et al., 2017). Symptoms of the inattentive subtype of ADHD are especially pronounced in preterm children relative to their NBW peers, though they also have more symptoms of the hyperactive-impulsive subtype (Franz et al., 2018; Scott et al., 2017; Scott et al., 2012; Taylor, Margevicius, Schluchter, Andreias, & Hack, 2015).

1.1 Attention deficits in early childhood and weaknesses in academic achievement

Numerous studies of the community samples unselected for prematurity document associations of early childhood attention problems and diagnoses of ADHD with later weaknesses in academic achievement (Duncan et al., 2007; Frazier, Youngstrom, Glutting, & Watkins, 2007; Lee & Hinshaw, 2006; Murray et al., 2017; Pingault et al., 2011; Polderman, Boomsma, Bartels, Verhulst, & Huizink, 2010; Taylor et al., 2015). These associations are more evident for the inattentive subtype of ADHD than for the hyperactive/impulsive subtype and are found even when controlling for sociodemographic characteristics, IQ, and comorbid conduct problems.

In one of the few longitudinal studies of low birth weight children examining associations of early attention problems with later achievement, Breslau et al. (2009) reported associations of parent and teacher ratings of attention problems at 6 years with scores on tests of reading and mathematics administered at age 17 years, even when controlling for IQ, socioeconomic status (SES), and comorbid behavior disorders. Jaekel et al. (2013) found similar associations of the inattentive subtype of ADHD and examiner ratings of attention problems at ages 6 and 8 years with poorer achievement at 13 years in groups of VPT/VLBW children and NBW controls. Diagnosis was based on a parent psychiatric interview and achievement measured by children's educational track and within-track performance in German secondary schools. Achievement was not associated with the hyperactive/impulsive subtype of ADHD or examiner ratings of children's activity level. Patterns of associations were similar in the VPT/VLBW and NBW groups and were evident even when controlling for IQ and neonatal and social factors.

1.2 Study aims and hypotheses

Despite evidence for associations of ADHD in young children with later achievement problems, past studies have not examined associations of ADHD diagnoses in EPT/ELBW children at school entry as predictors of early growth in achievement. Information is also lacking on whether assessment of ADHD complements cognitive testing in predicting early achievement in this population. The primary aim of this study was to examine associations of kindergarten assessments of ADHD with early learning progress in an EPT/ELBW cohort and NBW controls. Learning progress was evaluated by performance on tests of reading,

spelling, and mathematics administered at yearly intervals across the first three school years. Predictors of these outcomes included an interview-based diagnosis of ADHD and symptom counts for inattentive and hyperactive-impulsive behaviors obtained during children's first year in kindergarten. Both categorical and dimensional assessments of ADHD are common in research on predictors of achievement in preterm children and provide complementary information (Franz et al., 2017; Jaekel et al., 2013; Johnson et al., 2016). Diagnoses are useful in identifying children who meet clinical criteria and in estimating rates of disorder. However, ADHD is also viewed as a continuously distributed trait, with distinctions between individuals with ADHD compared to those who fall just short of meeting diagnostic criteria representing more of a quantitative difference than a qualitative one (Sonuga-Barke & Halperin, 2010). The advantage of considering symptom severity is that it takes this continuum into account in examining associations with other outcomes and may provide greater power for statistical analysis (Angold & Costello, 2009).

A further aim was to determine if associations of ADHD with poorer early learning progress would be found even when controlling for the effects other behavior disorders and for weaknesses in cognitive ability as measured by tests of IQ and executive function. As other behavior disorders and lower IQ are associated with both ADHD and poor academic achievement (Breslau et al., 2009; Massetti et al., 2008), associations of ADHD with achievement that are independent of potential confounds would suggest effects related to ADHD as opposed to other factors. The rationale for controlling for executive function skills is that weaknesses in this ability domain are well documented in EPT/ELBW children, partially independent of weaknesses in IQ or acquired knowledge, and related to academic skills (Aaronoudse-Moens, Weisglas-Kuperus, Duivenvoorden, van Goudoever, & Oosterlaan, 2013; Akshoomoff et al., 2017; Orchinik et al., 2011; Scott et al., 2017; Simms et al., 2014). Deficits in executive function are found in both community and preterm samples of children with attention problems or ADHD and are especially pronounced in children with the inattentive subtype of ADHD (Biederman et al., 2005; Diamond, 2005; Mulder, Pitchford, & Marlow, 2010; Nadeau, Boivin, Tessier, Lefebvre, & Robaey, 2001; Willcutt, Doyle, Nigg, Faraone, & Pennington, 2005). Biederman et al. (2004) found that children recruited from health clinics with ADHD with coexisting impairments in executive function had worse academic outcomes than those without impairments in executive function, but that even participants with ADHD who did not have such impairments had poorer outcomes than children without ADHD. A recent study confirmed associations of executive function skills in kindergarten with early development of achievement skills in EPT/ELBW children and NBW controls (Taylor et al., 2018) but did not examine associations of ADHD with achievement.

The primary study hypothesis was that a caregiver-based diagnosis of ADHD and higher ADHD symptom counts in kindergarten would be associated with slower growth in achievement skills or poorer achievement across the early school years for both the EPT/ELBW and NBW groups, and that these associations would be more pronounced for inattentive symptoms than for hyperactive-impulsive symptoms. A second hypothesis was that a diagnosis of ADHD and ADHD symptom counts would predict slower academic progress or poorer achievement across school years controlling for other psychiatric diagnoses and scores on tests of IQ or executive function. Tests of the latter hypothesis were

warranted to determine if associations with ADHD were independent of behavioral and cognitive comorbidities and if non-cognitive attributes of ADHD, such as motivational problems and delay aversion, might merit consideration as potential contributors to poor achievement (Fair, Bathula, Nikolas, & Nigg, 2012; Lambek et al., 2010; Nigg, Willcutt, Doyle, & Sonuga-Barke, 2005; Sonuga-Barke, Bitsakou, & Thompson, 2010; Willcutt, Doyle, Nigg, Faraone, & Pennington, 2005).

2. METHOD

2.1. Participants

All of the 198 surviving EPT/ELBW children without congenital anomalies or infections born in the years 2001–2003 and hospitalized in the neonatal intensive care unit of a large, urban children's hospital were eligible for the study, of whom 148 (75%) were recruited during their first year in kindergarten. Comparison of the children recruited to non-participants failed to reveal significant differences in sex, race, or neonatal characteristics (Scott et al., 2012). As the caregivers of 3 children did not complete a psychiatric interview and 6 children had severe developmental limitations that precluded meaningful assessment of behavior, 139 EPT/ELBW children were included in this study.

A group of 111 NBW children was also recruited in kindergarten by sending out flyers to the classmates of each EPT/ELBW child who was attending a regular kindergarten classroom. Flyers were distributed after each EPT/ELBW was assessed with permission from their caregivers. From among the classmates whose caregivers returned signed flyers agreeing to be contacted, consent was obtained for the NBW child who best matched the EPT/ELBW child on age at assessment (within 3 months), sex, and race. Given the study's focus on academic progress in EPT/ELBW children relative to school-based expectations, age was defined as chronological rather than conceptional or "corrected" age (Wilson & Cradock, 2004). If a classroom match was not available, the control child was recruited from a different classroom in the same school or in a different but demographically similar school (i.e., a school in the same school district or a district that was similar in terms of its urban, suburban, or rural location). Controls were not obtained for 3 EPT/ELBW children who were home schooled or 16 attending full-time self-contained special education programs. For 18 additional EPT/ELBW children, appropriate matches could not be found or the schools they attended refused participation or were located too distant from the medical center. The study was approved by the Institutional Review Board of the University Hospitals Cleveland Medical Center. Parents provided informed consent for children's participation and child assent was obtained for children ages 7 years and older.

2.2 Procedure

Children were assessed in a half-day session during their kindergarten year on measures of academic achievement, behavior, and cognitive ability. Information on family background characteristics, including parental educational and occupational status and family residence, were also collected at this time from caregivers. Caregivers were primarily biological or adoptive mothers (91.6%) but also included fathers (4.8%) and grandparents (3.6%). Details regarding the neuropsychological test battery and scoring procedures are provided in a

previous report (Orchinik et al., 2011). From the extensive test battery, only scores on tests of IQ and executive function were considered for this study given an interest in associations of ADHD with achievement that were independent of these factors. A structured psychiatric interview of caregivers, the Children's Interview for Psychiatric Syndromes-Parent version, or P-ChIPS (Fristad, Teare, Weller, Weller, & Salmon, 2010; Weller, Weller, Teare, & Fristad, 1999) was conducted as part of this assessment (described below). The assessments also included administration of the Child Behavior Checklist to caregivers and the Teacher's Report Form (Achenbach & Rescorla, 2001) to teachers. However, findings from the latter rating scales were not considered in assessment of ADHD as the P-ChIPS provided a more comprehensive assessment of diagnostic criteria for ADHD and other psychiatric disorders. Additional rationale for reliance on the P-ChIPS included the fact that teacher ratings were obtained only for children attending regular educational classrooms and previous research that supports the validity of parent observations of children's behavior as predictors of school performance and raises concerns regarding the sensitivity and stability of teacher ratings of inattentive symptoms in young children (Leviton et al., 2017; Massetti et al., 2008; Rabiner et al., 2010). Assessments were repeated annually for the next two school years at approximately 1-year intervals.

2.3 Measures

Kindergarten diagnoses of ADHD-Inattentive, ADHD-Hyperactive/Impulsive, and ADHD-Combined were made based on information obtained from the P-ChIPS. The P-ChIPS is a psychiatric interview that assesses child psychological disorders based on DSM-IV criteria for symptom counts, duration, and impairment. Consistent with diagnostic criteria applied to young children in a previous study (Massetti et al., 2008), diagnosis required parent endorsement of symptom-related impairment in one or more settings. Compared with clinical diagnoses the P-ChIPS has an average sensitivity and specificity across diagnostic categories of 0.87 and 0.76, respectively. The P-ChIPS is a structured interview developed for children 6–18 years. Although 140 children (56% of the sample) were <6 years at the time of assessment, the interview is appropriate for younger children attending school. Reliability was confirmed in a previous report (Scott et al., 2012) by review of a random selection of 25 video-taped interviews, which indicated 96–100% agreement on diagnostic syndromes and 92–100% agreement on symptom counts. Symptom counts for inattentive and hyperactive-impulsive behaviors and the sum of these two counts were also tallied. Other (non-ADHD) diagnoses on the P-ChIPS that were considered in this study included Oppositional Defiant Disorder, Conduct Disorder, Specific Phobia Disorder, Social Phobia Disorder, Separation Anxiety Disorder, Generalized Anxiety Disorder, Obsessive Compulsive Disorder, PTSD Disorder, Acute Stress Disorder, Major Depressive Disorder, Dysthymic Disorder, Mania Disorder, Hypomania Disorder, Schizophrenia Disorder, Psychosis Disorder, Anorexia, and Bulimia.

Academic achievement was assessed using tests of reading decoding, spelling to dictation, mathematics concepts and problem solving, and written arithmetic. Performance in these areas was measured, respectively, by children's W scores on the Letter-Word Identification, Spelling, Applied Problems, and Calculation tests from the Woodcock Johnson Tests of Achievement, 3rd Edition (Woodcock, McGrew, & Mather, 2001a). As equal-interval

transformations of raw scores, W scores are more sensitive to developmental change than age-standardized scores and thus preferred in assessing within-subject change (Jaffe, 2009).

IQ was estimated using the Brief Intelligence Assessment (BIA) from the Woodcock Johnson Tests of Cognitive Ability, 3rd Edition (Woodcock, McGrew, & Mather, 2001b). The BIA is a composite of tests of verbal knowledge, abstract reasoning, and performance skills (Verbal Comprehension, Concept Formation, and Visual Matching), has been validated in relation to other IQ measures, and has good reliability.

Tests of executive function included four tasks developed for assessment of young children. Shape School requires the child to name the color or shape of a series of cartoon-like figures in conditions varying in instructional set (Espy, Bull, Martin, & Sroup, 2006). Inhibition is measured by requiring naming of the color of happy but not sad figures, and shifting by requiring naming of either the color or shape depending on whether of the figure is wearing a hat. Performance in each condition was defined as the number correct/time.

For the Trials-Preschool Test-Revised, adapted from Espy and Cwik (2004), the child stamps cartoon dogs and their correspondingly sized bones on laminated sheets in order of increasing size. Inhibition is assessed by a condition in which the child stamps only the bones after having stamped only dogs, and shifting by having the child stamp each dog and then that dog's bone in order of increasing size. Performance in each condition was computed as $\text{speed}/\sqrt{\text{errors}+1}$.

In the computerized Test of Inhibition and Attention, adapted from Simpson and Riggs (2006), the child observes a series of cartoon fish and sharks and is required to press the space bar for fish but not for sharks. In the first or Go No-Go condition, fish appear on 75% of the trials, placing an emphasis on inhibition to the less frequently appearing sharks. On the second or Continuous Performance Test condition, the fish appear on only 25% of the trials, placing more emphasis on selective attention for the less frequently appearing fish. Performance in each condition is summarized by a signal detectability measure, $d' = Z(\text{hit rate}) - Z(\text{false alarm rate})$, where Z represents the inverse of the cumulative Gaussian distribution.

Nebraska Barnyard, adapted from the Noisy Book task (Hughes, Dunn, & White, 1998), is a computerized task that displays a group of farm animals, each pictured in a different color, on a touch screen. The examiner first familiarizes the child to the task by pressing each animal on the screen, which results in the animal making its corresponding animal sound. The examiner then reads increasingly longer series of animal names to the child and the child is instructed to press colors on the screen that correspond to the named animals in the same order as read by the examiner. Performance is summarized by the number of sequences the child is able to correctly reproduce until failing two successive trials.

Previous research confirms the appropriateness of these measures of selective attention and inhibition, mental set shifting, and working memory for young children and suggests acceptable levels of reliability and validity in relation to other measures of executive function (Espy, Bull, Martin, & Sroup, 2006; Espy & Cwik, 2004; Simpson & Riggs, 2006; Weibe, Sheffield, Nelson, Clark, Chevalier, & Espy, 2011). To assess executive function

relative to age expectations, a z score was computed for each of the 7 executive function scores. The z-score was defined as the difference in z-score units between observed scores and scores adjusted for age based on associations of age to scores within the NBW group. In keeping with a single-factor model of executive function in young children (Wiebe, Espy, & Charak, 2008), the z scores were then averaged to form an executive function composite.

2.4 Data analysis

The primary hypothesis was tested by conducting a mixed model analyses (Singer, 1998) of the effects of ADHD and related symptom counts on each of the four measures of academic achievement. The high correlation of symptom counts for inattention and hyperactivity-impulsivity ($r=.72$, $p<.001$) justified separate analysis of these counts to avoid multicollinearity. Other factors included in these primary or base models were group (EPT/ELBW vs. NBW) and assessment year (1–3). To assess growth in achievement both early in follow-up and across the both follow-up years, the effects of year consisted of two components representing change from years 1 to 2 and 1 to 3. Differential change in the two groups was modeled by specifying the change in the EPT/ELBW group relative to change in the NBW group. Similarly, differential change on the achievement measures in children with ADHD versus no ADHD was modeled by specifying change in children with ADHD relative to change in those without ADHD; or in modeling symptom counts, change in achievement in relation to higher symptom counts. Interactions of the presence/absence of ADHD or higher symptom counts with group, year, and the group x year effect were also included in the analysis. The final models for each achievement measure were obtained by trimming non-significant higher-order and then lower-order interaction effects.

Covariates in the base models were zSES as defined by the mean of the sample z scores for maternal education, caregiver occupation, and census-based median family income (Orchinik et al., 2011), and number of weeks in kindergarten (to control for learning due to increasing time in kindergarten). Family membership was also included in the models as a cluster variable to account for non-independence of scores for siblings. As preliminary analysis failed to reveal associations of sex or either chronological or corrected age at assessment with any of the achievement measures, these factors were excluded from the models. Race was also excluded due to its moderate correlation with zSES ($r = .50$, $p<.001$).

The second hypothesis was tested by extending the base models to include the presence/absence of another (non-ADHD) diagnosis on the P-ChIPS and either the BIA or executive function composite as predictors. The two cognitive scores were highly correlated ($r=.78$, $p<.001$) and thus examined in separate models. Adjustments for time in school were not made to these measures given the lack of evidence for associations of this factor with test scores (Orchinik et al., 2011).

To adjust for analysis of multiple achievement measures, statistical significance was defined by a Bonferroni-corrected $p<.0125$ ($.05/4$). Effect sizes for differences in achievement scores between children with ADHD vs. no ADHD were computed using Cohen's d (Cohen, 1992). Small, medium, and large effect sizes correspond to d 's of 0.2, 0.5, and 0.8. Missing data were minimal and reflected child noncompliance on select cognitive tasks.

3. RESULTS

3.1 Sample characteristics

Sample characteristics at the time of the initial kindergarten assessment are summarized in Table 1. The EPT/ELBW and NBW groups did not differ significantly in chronological age at assessment, sex, or zSES, although the mean time in kindergarten at assessment was significantly shorter for the EPT/ELBW group than for the NBW controls. Most participants with diagnoses of ADHD met criteria for the Combined subtype, with only 11 meeting criteria for the Inattentive subtype who were not also diagnosed with the Combined subtype. Children were thus classified as having any vs. no ADHD diagnosis. The EPT/ELBW group had a higher proportion of children with ADHD, higher symptoms counts, and lower scores on the BIA, executive function composite, and most of the achievement tests. Rates of ADHD were not significantly different for males than females in the total sample (28% vs. 18%, $p=.058$) or EPT/ELBW group (31% vs. 25%, $p=.439$), but were higher for males than females in the NBW group (24% vs. 8%, $p=.027$).

As indicated in Table 1, despite comparable rates of preschool attendance (i.e., programs for children prior to attending kindergarten, typically prior to age 5 years), the EPT/ELBW group had higher rates of special preschool programs (often referred to as “early intervention”) prior to kindergarten, as well as higher rates of individualized education programs (IEPs) in kindergarten. The most common classifications for IEPs were for learning disabilities (35%) and speech-language impairment (33%), but classifications varied widely and information on the basis of classification was not available. Rates of IEPs remained higher in the EPT/ELBW group than in NBW controls in years 2 and 3, with IEPs assigned to 46 children in the EPT/ELBW group (35%) compared to 12 controls (11%) in year 2, and 49 EPT/ELBW children (40%) compared to 14 controls (14%) in year 3, both $p's<.001$. Significantly more children with ADHD than without ADHD had IEPs in kindergarten (46% vs. 21%, $p=.002$). Rates of grade repetition in years 2 or 3 were not significantly higher for EPT/ELBW children than for NBW controls ($n = 13$, 9% vs. $n = 4$, 4%, $p=.123$).

Seventeen children (12 EPT/ELBW, 5 NBW) were diagnosed with ADHD by their physicians prior to the kindergarten assessment, all but one of whom met criteria for ADHD on the P-ChIPS. Nine of these children were receiving medications for behavior problems at the time of the kindergarten assessment (7 EPT/ELBW, 2 NBW), 8 of whom met criteria for ADHD on the P-ChIPS. Children diagnosed with ADHD on the P-ChIPS but without a pre-existing diagnosis of ADHD included 28 of 39 EPT/ELBW children and 12 of 17 NBW controls. In support of the convergent validity of the P-ChIPS, children diagnosed with ADHD had higher rates of scores in the clinical range (T score $\geq 93^{\text{rd}}$ percentile) on the DSM-Oriented Attention Deficit Hyperactivity Problems scale of the CBCL and TRF than those without ADHD (both $p's<.001$).

Children remaining in the study in year 2 included 130 EPT/ELBW children (94% of the group enrolled in kindergarten) and 107 NBW controls (96%), and those remaining in year 3 included 123 EPT/ELBW children (89%) and 102 NBW controls (92%). Mean ages (SDs) for the EPT/ELBW and NBW groups, respectively, were 7.0 (0.4) and 7.0 (0.3) in year 2,

and 8.0 (0.4) and 8.0 (0.3) in year 3. Although children who completed the study did not differ significantly from non-completers in group membership, zSES, sex, or age at the initial assessment, a higher proportion of white compared to black families completed the study (95% vs. 86%, $p=.021$). Comparisons of EPT/ELBW children who completed the study to those who dropped out failed to reveal differences in neonatal characteristics as listed in Table 1.

3.2 Relation of ADHD and symptom counts in kindergarten to achievement: base models

Table 2 lists results from models examining the association of ADHD in kindergarten with growth in achievement across years 1–3. ADHD was associated with slower growth in Letter-Word Identification, as well as with lower scores in all three years (but not differential growth) in Applied Problems. Effect sizes for differences between children with vs. without ADHD on the four achievement tests ranged from small to moderate and increased over time (d 's of 0.13–0.46 in year 1, 0.17–0.50 in year 2, and 0.44–0.52 in year 3). Figure 1 illustrates slower growth in Letter-Word Identification for children with ADHD compared to those without this diagnosis.

Even with a diagnosis of ADHD in the models, the EPT/ELBW children obtained significantly lower scores than NBW controls on Spelling, Calculation, and Applied Problems, indicating additive effects of ADHD and preterm birth on achievement. Other effects summarized in Table 2 include significant increases in W scores across years, associations of lower achievement levels with lower zSES, and faster growth in Spelling for the EPT/ELBW group compared to controls, suggesting a partial catch-up in this skill in the former group. Group differences in achievement have been described previously (Taylor et al., 2018) and were not the focus of this study.

To further explore the associations of the ADHD-Inattentive compared to ADHD-Hyperactive/Impulsive subtypes of ADHD, two series of sensitivity analyses were conducted. The first series excluded the 22 children meeting criteria for ADHD-Hyperactive/Impulsive only, whereas the second excluded the 7 children meeting criteria for ADHD-Inattentive only. Although both series included children meeting criteria for ADHD-Combined, these analyses examined the presence of each subtype considered separately as a predictor of achievement. Results indicated that both ADHD subtypes were associated with lower scores in all years (but not differential growth) in Applied Problems, but only ADHD-Inattentive was associated with slower growth in Letter-Word Identification and Calculation and lower scores in all years (but not differential growth) in Spelling (p 's < .0125) (see Supplemental Table 1).

Analysis of symptom counts in relation to achievement scores revealed similar findings (Table 3). Higher levels of all three symptoms counts were associated with slower progress in Letter/Word Identification; higher inattentive and total symptom counts were associated with slower progress in Calculation; and higher levels of all three counts were associated with lower scores in all years (but not differential growth) in Spelling and Applied Problems (all p 's < .0125).

3.3 Relation of ADHD and symptom counts in kindergarten to achievement controlling for other behavior disorders and cognitive ability

In models that included the presence/absence of another (non-ADHD) diagnosis and the BIA as predictors of achievement in addition to ADHD (Supplemental Table 2), a lower BIA was associated with lower scores on all achievement tests, and ADHD was associated with slower growth in Letter-Word Identification. In models that included another (non-ADHD) diagnosis and the executive function composite in addition to ADHD (Supplemental Table 3), a lower executive function composite was associated with lower scores on all achievement tests, and ADHD was associated with slower growth in Letter-Word Identification (all p 's<.0125). A diagnosis of another (non-ADHD) diagnosis was not significantly associated with achievement in these models.

Models that included the presence/absence of another (non-ADHD) diagnosis and either the BIA or executive composite as predictors of achievement in addition to symptom counts revealed similar findings (see Supplemental Tables 4 and 5). In models that included either the BIA or executive function composite in addition to symptoms counts, higher levels of all three symptom counts were associated with slower progress in Letter/Word Identification, and higher inattentive and total symptom counts were associated with slower progress in Calculation (all p 's<.0125).

4. DISCUSSION

This study examined associations of an interview-based ADHD diagnosis and related symptom counts as assessed in kindergarten with early school-age progress in academic achievement in a sample of EPT/ELBW children and NBW controls. Over and above the adverse effects of preterm birth on achievement test scores, a psychiatric interview-based diagnosis of ADHD in kindergarten predicted slower growth across the first three school years in word reading, as well as lower scores in all three years in mathematics applications. Analyses of symptom counts revealed associations of higher symptom counts for both inattentive and hyperactive-impulsive behaviors with slower growth in word reading and with poor achievement in all years in spelling and mathematics applications, although only higher counts of inattentive symptoms were associated with slower growth in written arithmetic. The results confirm previous research documenting both categorical and dimensional measures of ADHD as complementary predictors of achievement in preterm/low birth weight and community samples (Breslau et al., 2009; DuPaul, Gormely, & Laracy, 2013; Jaekel et al., 2013; Johnson et al., 2016; Lee & Hinshaw, 2006; Massetti et al., 2008; Polderman et al., 2010). Prediction of achievement from symptom counts suggests that risks for achievement problems in the early grades vary along a continuum and that symptoms of ADHD in kindergarten, even if not accompanied by a diagnosis, raise concerns about children's future academic progress.

To our knowledge this is the first study of preterm/low birth weight children to document associations of ADHD with slower growth in achievement across the early school-age years. This is also the only study of preterm children of which we are aware to demonstrate associations of ADHD with achievement independent of both other psychiatric disorders and children's performance on tests of executive function. The findings are consistent with

research on community samples documenting slower rates of early academic progress in children with ADHD (Alexander, Entwisle, & Dauber, 1993; Biederman et al., 1996) and indicate that ADHD and preterm birth make additive contributions to the risk for early learning problems.

A recent meta-analysis by Franz et al. (2018) documented higher rates of ADHD and more symptoms of both inattentive and hyperactive-impulsive behavior in EPT/ELBW and VPT/VLBW cohorts compared to NBW controls. The greater frequency of both symptom types in the EPT/ELBW group compared to NBW controls is consistent with these findings. Rates of ADHD in the EPT/ELBW and NBW groups (28% and 15%, respectively) were high relative to rates reported in previous studies (Johnson & Marlow, 2011), including a study comparing a VPT group to full-term controls in rates of ADHD and ADHD symptoms at 6 years of age (Jaekel et al., 2013). The higher-than-anticipated rates observed in the present study may reflect the heterogeneity in ADHD documented in the meta-analysis by Franz et al. (2018) and are consistent with the heightened rates of ADHD found in urban populations (Breslau et al., 1996; Szatmari, 1992). The relatively high rates of ADHD in the present sample are also in line with the rates of elevated parent ratings of ADHD symptoms in EPT children and NBW controls reported by Samuelsson et al. (2017). The absence of sex differences in rates of ADHD in the EPT/ELBW group is contrary to previous reports indicating a greater vulnerability of preterm males to ADHD (Johnson, 2007) but is not unexpected given mixed findings in this regard (Franz et al., 2018).

Associations of symptoms of hyperactivity-impulsivity and the ADHD-Hyperactive/Impulsive subtype with slower growth in achievement or poorer achievement across the early grades may reflect the sensitivity of parents of young children to hyperactivity and difficulties in motor control as an early manifestation of attention problems (Masseti et al., 2008; Nelson, James, & Espy, 2016). The high correlation of inattentive and hyperactive-impulsive symptom counts and the considerable overlap of ADHD-Inattentive and ADHD Hyperactive/Impulsive subtypes support this interpretation. However, the hypothesis that symptoms of inattention would be more strongly related to achievement than symptoms of hyperactivity-impulsivity was partially confirmed. In sensitivity analyses examining the separate effects of the two diagnostic subtypes, only children meeting diagnostic criteria based on inattentive symptoms (i.e., not those who met criteria based on hyperactive-impulsive symptoms) made slower progress in word recognition and written arithmetic and had lower scores in all years in spelling. Similarly, in analysis of symptom counts, fewer symptoms of inattention (but not of hyperactivity-impulsivity) were associated with slower growth in written arithmetic. The more extensive associations of inattentive symptoms with academic progress may be explained in terms of the greater comorbidity of the inattentive subtype with learning disabilities and deficits in working memory and processing speed (Diamond, 2005).

Associations of ADHD with academic underachievement may reflect negative effects of inattention on learning or weaknesses in achievement that make it difficult for children to stay on task (Breslau et al., 2009; Massetti et al., 2008). Although family histories of ADHD were not obtained in this study, the relation of genetic factors and neural abnormalities to both learning and behavioral self-regulation may also contribute to these associations

(Boada, Willcutt, & Pennington, 2012; Massetti et al., 2008). Symptoms of inattentiveness in EPT/ELBW children have been linked to reductions in cortical white matter and smaller head circumference (Johnson & Marlow, 2011; Johnson et al., 2016; Jaekel et al., 2013), but abnormalities in brain development are documented even in the broader population of individuals with ADHD (Mackie et al., 2007; Shaw et al., 2006; Wolosin, Richardson, Hennessey, Denckla, & Mostofsky, 2009). The lack of associations of achievement with diagnoses other than ADHD replicates results from some but not all previous studies (Beiderman et al., 1996; Breslau et al., 2009; Duncan et al., 2007; Massetti et al., 2008) and suggests that ADHD may be more closely related to early learning difficulties than other psychiatric disorders.

Results indicating that ADHD was associated with achievement independent of scores on tests of global cognitive ability and executive function suggest that assessment of ADHD provides “value-added” information relevant in forecasting achievement. Consistent with these findings, two studies found independent or synergistic effects of ADHD and deficits in executive function on achievement or school performance (Beiderman et al., 2004; Diamantopoulos, Rydell, Thorell, & Bohlin, 2007). Another investigation documented independent effects of ADHD symptoms and lower scores on measures of executive function at ages 5 and 6 years as predictors of a lower grade point average in late adolescence (Sjöwall, Bohlin, Rydell, & Thorell, 2017). A further study found independent associations of higher parent ratings of working memory problems and lower scores on tests of this ability domain with poorer reading comprehension and math computation in fourth and fifth grade students (Gerst, Cirino, Fletcher, & Yoshida, 2017). Independent effects of IQ and ADHD on achievement are also documented (Jaekel et al., 2013; Scott et al., 2017). These independent associations may be attributed to unmeasured deficits in children with ADHD in cognitive domains such as temporal information processing, response variability, or arousal, or by non-cognitive impairments in areas such as motivation and delay aversion (Fair, Bathula, Nikolas, & Nigg, 2012; Lambek et al., 2010; Nigg, Willcutt, Doyle, & Sonuga-Barke, 2005; Sonuga-Barke, Bitsakou, & Thompson, 2010; Willcutt et al., 2005). An additional possibility is that tests provide measures of attentional and executive function capacities, whereas parent reports reflect the application of these capacities in the context of environmental demands and supports (Gerst et al., 2017).

Strengths of this study include comparison of EPT/ELBW children to matched NBW peers from the same or similar classrooms, use of a psychiatric interview to evaluate ADHD, and longitudinal evaluation of learning progress. The procedure of matching EPT/ELBW children to NBW peers yielded a control group that was similar in background characteristics to the EPT/ELBW cohort. Johnson (2007) emphasizes the greater rigor provided by interviews compared to rating scales in assessing behavioral outcomes of preterm birth, and Holmbeck, Bruno, and Jandasek (2006) describe the advantages of longitudinal designs, including tracking of individual progress and more precise estimates of age-related change.

One of the study’s limitations is that psychiatric diagnoses were based on the P-ChIPS rather than on comprehensive clinical interviews and that evidence for ADHD was not obtained across multiple settings. A further limitation of the P-ChIPS is that it does not evaluate

autism spectrum disorder, a condition that is more prevalent in EPT children than in the general child population (Joseph et al., 2017). Thus, the effects of ADHD on achievement could not be examined independent of this diagnosis. Although findings may differ from those based on more extensive psychiatric evaluations, past research confirms the validity of caregiver reports of ADHD symptoms in early childhood as predictors of achievement (Breslau et al., 2009; Diamantopoulos et al., 2007; Jaekel et al., 2013; Scott et al., 2017; Vitaro, Brendgen, Larose, & Tremblay, 2005) and in discriminating preterm children from NBW controls (Franz et al., 2018; Jaekel et al., 2013; Samuelsson et al., 2017). One virtue of a structured interview like the P-ChIPS is that it considers diagnostic criteria not evaluated using parent or teacher ratings alone, including symptom duration and associated functional impairment. A further advantage is that symptom presence/absence is queried orally rather than on a written questionnaire, which may facilitate caregivers' understanding and engagement in answering questions. Previous research suggests that parent report alone is of value and that teachers may be less aware of inattentiveness at early school age because of the low level of demands placed on children at this age (Lahey et al., 2004; Leviton et al., 2017; Massetti et al., 2008). One study found that rates of clinically significant inattention in VPT children compared to NBW controls were evident on parent but not teacher ratings, and that the higher frequency of ADHD symptoms in the VPT group was evident even in children who were not identified by their teachers as having special education needs (Brogan, Cragg, Gilmore, Marlow, & Johnson, 2014).

Other limitations are recruitment from a largely urban catchment area that may not be representative of the broader population and a sample size that yielded too few children with predominately inattentive or hyperactive/impulsive symptoms to rigorously examine the effects of ADHD subtype. Additionally, the present study focused on a diagnosis of ADHD in kindergarten and its relation to achievement across only the first three years in school. Further investigation is warranted to determine the longer-term academic consequences of early ADHD. Although ADHD in young children and associated achievement problems are likely to persist (Biederman et al., 1996; Breslau et al., 2009; Jaekel et al., 2013; Lahey et al., 2004; Langberg et al., 2011; Lee & Hinshaw, 2006; Pingault et al., 2011; Vitaro et al., 2005), ADHD may resolve in some children or emerge later in childhood in others (Murray et al., 2017; Sonuga-Barke & Halperin, 2010). Factors to consider in accounting for longer-term achievement outcomes include age-related changes in ADHD symptoms and cognitive abilities, SES, parenting style, student-teacher relationships, classroom performance, and children's prosocial traits (Breslau et al., 2010; Coghill, Hayward, Rhodes, Grimmer, & Matthews, 2014; Costa et al., 2017; Langberg et al., 2011; McCauley, Crosbie, Charach, & Schachar, 2017; Pingault et al., 2011; Vitaro et al., 2005). Measures of specific types of executive function also need to be considered in predicting achievement at later ages. A single composite measure of this skill domain was justified for this study given the young age of the sample (Wiebe et al., 2008). However, past research indicates that distinct skills within this domain, including working memory, inhibition, and set switching, are differentially related to different aspects of academic competence in older children (Bull & Scerif, 2001; Fadaei et al., 2017; Gerst et al., 2017).

In conclusion, follow-up of a cohort of EPT/ELBW children and NBW classmates across their first three years in school revealed that a caregiver-based diagnosis of ADHD and

related symptoms in kindergarten were associated with slower growth in academic skills or lower levels of achievement across the early grades. Both inattentive and hyperactive-impulsive symptoms were related to these outcomes, suggesting associations with higher symptom levels as well as a diagnosis of ADHD. Although associations of ADHD with achievement outcomes did not differ by group, EPT/ELBW children have elevated rates of ADHD, especially the Inattentive subtype, compared to their NBW peers (Johnson et al., 2016; Taylor et al., 2015) and are thus at higher risk for poor learning progress and academic interventions. Both ADHD and scores on tests of intelligence and executive function were significantly related to achievement in analyses that considered their conjoint effects. The findings provide impetus for efforts to identify children at risk for early academic difficulties, especially in higher-risk groups such as preterm children. The results also support the use of behavioral assessments of ADHD as complements to cognitive testing in identifying high-risk children. Early identification of ADHD may be especially critical in view of findings that most of the children who met our research criteria for the disorder had not been diagnosed previously. Associations of ADHD at school entry with slower subsequent growth in academic skills make it paramount to initiate early intervention and consider multimodal approaches that address problems in both attention and academic achievement (Biederman et al., 2004; Massetti et al., 2008; Pingault et al., 2011; Scott et al., 2017).

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Highlights:

- The diagnosis of ADHD in kindergarten predicts early growth in achievement
- ADHD symptoms in kindergarten also predict growth in achievement
- ADHD predicts achievement independent of the effects of prematurity
- ADHD predicts achievement independent of other diagnoses and cognitive ability
- ADHD young at-risk children is useful in identifying needs for early intervention

Figure 1.

Model estimates of mean W scores for Letter-Word Identification in children with ADHD compared to children without ADHD (No ADHD) across years 1–3. Findings illustrate significantly slower growth in word recognition ability across years in school in the group with ADHD.

Table 1.

Sample Characteristics.

Characteristic	Group			p
	EPT/ELBW (n = 139)	Group NBW (n = 111)	χ ² or t-test	
Neonatal status:				
Birth weight in grams, mean (SD)	818 (172)	3382 (446)	t(244)=−56.31	<.001
Gestation age in weeks, mean (SD)	26 (2)	37		
Small for gestational age, n (%)	36 (26%)	—		
Multiple birth, n (%)	29 (21%)	0 (0%)	χ ² (1)=26.20	<.001
Severely abnormal cranial ultrasound, ^a n (%)	9 (7%)	—		
Bronchopulmonary dysplasia, ^b n (%)	74 (53%)	—		
Infection or necrotizing enterocolitis, n (%)	56 (40%)	—		
Severe retinopathy of prematurity, ^c n (%)	24 (17%)	—		
Preschool placements:				
Preschool attendance, n (%)	116 (84%)	94 (85%)	χ ² (1)=0.07	.792
Early intervention services, n (%)	114 (82%)	14 (13%)	χ ² (1)=118.97	<.001
Kindergarten demographic status:				
Age in years, mean (SD)	5.93 (0.34)	5.96 (0.31)	t(248)=−0.80	.425
Months in current grade, mean (SD)	4.22 (2.32)	6.38 (1.72)	t(246.60)=−8.45	<.001
Male, n (%)	64 (46%)	51 (46%)	χ ² (1)=0.00	.988
African American, n (%)	85 (61%)	61 (55%)	χ ² (1)=0.98	.323
zSES, mean (SD)	−0.05 (1.00)	0.07 (0.98)	t(248)=−0.97	.333
Kindergarten diagnoses and symptoms counts: ^d				
Diagnosis of ADHD, n (%)	39 (28%)	17 (15%)	χ ² (1)=5.77	.016
Diagnosis comorbid with ADHD, n (% of ADHD group)	20 (51%)	8 (47%)	χ ² (1)=0.08	.771
Diagnosis other than ADHD, n (%)	29 (21%)	18 (16%)	χ ² (1)=0.87	.350
Symptom count for inattentive symptoms, mean (SD)	3.00 (2.93)	1.33 (2.31)	t(247.98)=5.03	<.001
Symptom count for hyperactive-impulsive symptoms, mean (SD)*	3.41 (2.91)	2.33 (2.67)	t(248)=3.02	.003
Symptom count for ADHD-I and ADHD-HI, mean (SD)	6.41 (5.46)	3.67 (4.52)	t(247.64)=4.35	<.001
Kindergarten cognitive and achievement status:				

Characteristic	Group			χ^2 or t-test	p
	EPT/ELBW (n = 139)	Group NBW (n = 111)			
Brief Intelligence Assessment (BIA), mean (SD)	88.26 (19.28)	105.49 (16.61)		t(242)=7.38	<.001
Executive function composite z score, mean (SD)	-1.19 (1.46)	0.00 (1.00)		t(237.98)=-7.54	<.001
Letter-Word Identification standard score, ^e mean (SD)	106.11 (16.02)	110.63 (13.01)		t(247)=-2.40	.017
Spelling standard score, ^e mean (SD)	92.18 (18.88)	101.41 (13.83)		t(243.65)=-4.44	<.001
Calculation standard score, ^d mean (SD)	102.40 (8.96)	105.24 (11.80)		t(153.00)=-1.70	.091
Applied Problems standard score, ^e mean (SD)	95.36 (19.70)	106.94 (18.05)		t(244)=-4.76	<.001
IEP in place at time of kindergarten assessment	54 (39%)	12 (11%)		$\chi^2(1)=24.97$	<.001

Abbreviations: EPT/ELBW = extremely preterm/extremely low birth weight; NBW = term-born normal birth weight; zSES = z score for socioeconomic status; ADHD = attention deficit hyperactivity disorder; IEP = Individualized Education Program (provision of special education).

^aDefined as clinician-identified Grade III/IV intraventricular hemorrhage, periventricular leukomalacia, or ventricular dilatation at discharge.

^bDefined as supplemental oxygen at 36 weeks corrected age.

^cDefined as Stage 4 or 5 retinopathy or treatment with cryotherapy or laser therapy.

^dDiagnoses of ADHD and other disorders, along with corresponding symptom counts, are from the parent version of the Children's Inventory of Psychiatric Syndromes (P-ChIPS). Diagnoses other than ADHD in the total sample included Oppositional Disorder (n = 34, 14%), Conduct Disorder (n = 12, 5%), Specific Phobia Disorder (n = 11, 4%), Social Phobic Disorder (n = 4, 2%), Separation Anxiety Disorder (n = 3, 1%), General Anxiety Disorder (n = 6, 2%), Obsessive Compulsive Disorder (n = 2, 1%), Acute Stress Disorder (n = 1, <1%), Major Depressive Disorder (n = 5, 2%), Dysthymic Disorder (n = 1, <1%), and Mania Disorder (n = 4, 2%). No child in the sample met criteria for any of the remaining disorders.

^eStandard score for grade on the Woodcock Johnson Tests of Achievement, 3rd Edition.

Table 2.

Results from mixed model analysis of W scores on tests of academic achievement in sample of EPT/ELBW children and NBW classmate controls—base models including the diagnosis of ADHD as a predictor.

Achievement Test: Effect	Letter-Word Identification Beta (se)	Spelling Beta (se)	Calculation Beta (se)	Applied Problems Beta (se)
Intercept	363.17 (6.24) *	399.52 (4.83) *	419.43 (3.16) *	426.33 (4.51) *
EPT/ELBW group (Yr1)	-10.59 (4.23)	-16.70 (3.31) *	-10.93 (2.23) *	-15.43 (3.14) *
zSES	14.02 (1.84) *	9.82 (1.42) *	5.82 (0.92) *	9.15 (1.31) *
Months in kindergarten	4.25 (0.87) *	3.72 (0.67) *	1.68 (0.43) *	1.80 (0.62) *
Yr1 to Yr2, NBW group	52.44 (2.06) *	38.30 (1.73) *	31.63 (1.89) *	25.62 (1.56) *
Yr1 to Yr3, NBW group	83.59 (2.62) *	58.36 (2.11) *	45.48 (1.74) *	42.38 (1.61) *
Additional Yr1 to Yr2, EPT/ELBW group	-2.82 (2.74)	4.27 (2.30)	-1.40 (2.53)	-1.35 (2.08)
Additional Yr1 to Yr3, EPT/ELBW group	0.80 (3.47)	9.64 (2.79) *	3.65 (2.32)	0.19 (2.13)
ADHD dx (Yr1)	-3.65 (4.51)	-6.64 (3.50)	-3.34 (2.47)	-9.92 (3.20) *
Additional Yr1 to Yr2 with ADHD dx	-1.75 (3.31)	-2.16 (2.79)	-2.98 (3.10)	-0.31 (2.51)
Additional Yr1 to Yr3 with ADHD dx	-11.70 (4.17) *	-6.13 (3.37)	-3.93 (2.86)	-0.58 (2.56)

Abbreviations: EPT/ELBW: extremely preterm/extremely low birth weight; Yr: year; NBW: term-born normal birth weight; ADHD: attention deficit hyperactivity disorder; zSES: z score for socioeconomic status.

Note: A diagnosis of ADHD (n=56) was assessed relative to no ADHD diagnosis (n=194). Effects defined as follows: EPT/ELBW group (Yr1): score for EPT/ELBW group relative to NBW group in kindergarten; zSES: change in score corresponding to 1 SD increase in zSES; Months in kindergarten: change in score for each additional month in kindergarten; Yr1 to Yr2, NBW group: change in score from year 1 to year 2 for NBW group; Yr1 to Yr3, NBW group: change in score from year 1 to year 3 for NBW group; Additional Yr1 to Yr2, EPT/ELBW group: change in score from year 1 to year 2 in EPT/ELBW group relative to corresponding change in NBW group; Additional Yr1 to Yr3, EPT/ELBW group: change in score from year 1 to year 3 in EPT/ELBW group relative to corresponding change in NBW group; ADHD dx: change in score for children with a given ADHD diagnosis relative to corresponding change for those with no ADHD diagnosis; Additional Yr1 to Yr2 with ADHD dx: change in score from year 1 to year 2 for children with a given ADHD diagnosis relative to corresponding change in children with no ADHD diagnosis; Additional Yr1 to Yr3 with ADHD dx: change in score from year 1 to year 3 for children with a given ADHD diagnosis relative to corresponding change in children with no ADHD diagnosis.

* $p < .0125$ (Bonferroni corrected p)

Table 3.

Results of mixed model analysis of W scores on tests of academic achievement in sample of EPT/ELBW children and NBW controls—base models including ADHD symptom counts as predictors.

Achievement Test	Effect	Symptom Count		
		inattentive	hyperactive-impulsive	total
Letter/Word Identification:	Intercept	366.62 (6.21) *	366.44 (6.49) *	367.52 (6.37) *
	EPT/ELBW group (Yr1)	−9.55 (4.26)	−10.56 (4.21)	−9.92 (4.24)
	zSES	12.95 (1.81) *	13.16 (1.88) *	12.73 (1.86) *
	Months in kindergarten	3.92 (0.85) *	4.00 (0.86) *	3.89 (0.86) *
	Yr1 to Yr2, NBW group	53.21 (2.11) *	53.53 (2.29) *	53.59 (2.22) *
	Yr1 to Yr3, NBW group	85.37 (2.63) *	86.34 (2.91) *	86.64 (2.79) *
	Additional Yr1 to Yr2, EPT/ELBW group	−1.68 (2.81)	−2.40 (2.75)	−1.99 (2.80)
	Additional Yr1 to Yr3, EPT/ELBW group	3.61 (3.49)	1.40 (3.48)	2.79 (3.49)
	ADHD symptoms	−1.39 (0.70)	−0.95 (0.68)	−0.70 (0.37)
	Additional Yr1 to Yr2 with ADHD symptoms	−0.76 (0.51)	−0.59 (0.48)	−0.39 (0.27)
Spelling:	Additional Yr1 to Yr3 with ADHD symptoms	−2.58 (0.63) *	−1.97 (0.61) *	−1.31 (0.33) *
	Intercept	402.94 (4.77) *	404.00 (4.97) *	404.64 (4.86) *
	EPT/ELBW group (Yr1)	−14.66 (3.29) *	−16.31 (3.26) *	−15.20 (3.26) *
	zSES	8.94 (1.38) *	8.89 (1.43) *	8.61 (1.41) *
	Months in kindergarten	3.47 (0.65) *	3.46 (0.66) *	3.41 (0.65) *
	Yr1 to Yr2, NBW group	38.29 (1.78) *	38.48 (1.93) *	38.44 (1.87) *
	Yr1 to Yr3, NBW group	59.05 (2.15) *	59.33 (2.36) *	59.55 (2.28) *
	Additional Yr1 to Yr2, EPT/ELBW group	4.35 (2.36)	4.23 (2.31)	4.33 (2.35)
	Additional Yr1 to Yr3, EPT/ELBW group	10.64 (2.85) *	9.69 (2.81) *	10.31 (2.84) *
	ADHD symptoms	−2.12 (0.53) *	−1.64 (0.52) *	−1.11 (0.29) *
	Additional Yr1 to Yr2 with ADHD symptoms	−0.21 (0.43)	−0.22 (0.41)	−0.12 (0.23)
	Additional Yr1 to Yr3 with ADHD symptoms	−1.15 (0.52)	−0.82 (0.50)	−0.57 (0.27)
	Calculation: Intercept	420.91 (3.13) *	421.91 (3.24) *	421.85 (3.18) *
	EPT/ELBW group (Yr1)	−10.39 (2.25) *	−10.77 (2.20) *	−10.48 (2.21) *
	zSES	5.26 (0.89) *	5.16 (0.92) *	4.99 (0.90) *
	Months in kindergarten	1.52 (0.42) *	1.52 (0.42) *	1.50 (0.42) *
	Yr1 to Yr2, NBW group	33.54 (1.89) *	33.32 (2.08) *	34.00 (2.00) *

Achievement Test	Effect	Symptom Count		
		inattentive	hyperactive-impulsive	total
Applied Problems:	Yr1 to Yr3, NBW group	47.38 (1.74) *	46.50 (1.93) *	47.55 (1.85) *
	Additional Yr1 to Yr2, EPT/ELBW group	0.81 (2.53)	-0.78 (2.52)	0.28 (2.53)
	Additional Yr1 to Yr3, EPT/ELBW group	5.68 (2.31)	3.91 (2.33)	5.00 (2.32)
	ADHD symptoms	-0.71 (0.39)	-0.84 (0.36)	-0.47 (0.20)
	Additional Yr1 to Yr2 with ADHD symptoms	-1.74 (0.47) *	-0.93 (0.45)	-0.77 (0.25) *
	Additional Yr1 to Yr3 with ADHD symptoms	-1.81 (0.43) *	-0.70 (0.41)	-0.72 (0.23) *
	Intercept	429.96 (4.37) *	430.60 (4.67) *	431.55 (4.50) *
	EPT/ELBW group (Yr1)	-13.29 (3.09) *	-15.22 (3.12) *	-13.90 (3.08) *
	zSES	8.25 (1.26) *	8.36 (1.34) *	7.91 (1.29) *
	Months in kindergarten	1.50 (0.59) *	1.56 (0.62)	1.48 (0.60)
	Yr1 to Yr2, NBW group	26.17 (1.60) *	25.47 (1.74) *	25.94 (1.69) *
	Yr1 to Yr3, NBW group	42.73 (1.64) *	42.34 (1.79) *	42.63 (1.74) *
	Additional Yr1 to Yr2, EPT/ELBW group	-0.68 (2.14)	-1.43 (2.10)	-1.15 (2.13)
	Additional Yr1 to Yr3, EPT/ELBW group	0.53 (2.18)	0.12 (2.14)	0.30 (2.17)
	ADHD symptoms	-2.41 (0.48) *	-1.80 (0.48) *	-1.27 (0.26) *
	Additional Yr1 to Yr2 with ADHD symptoms	-0.41 (0.38)	0.05 (0.37)	-0.10 (0.20)
	Additional Yr1 to Yr3 with ADHD symptoms	-0.29 (0.39)	-0.02 (0.38)	-0.09 (0.21)

Abbreviations: EPT/ELBW: extremely preterm/extremely low birth weight; NBW: term-born normal birth weight; ADHD: attention deficit hyperactivity disorder; Yr: year; zSES: z score for socioeconomic status.

Note: Counts are for all children regardless of whether they meet criteria for an ADHD diagnosis. Effects defined as follows: EPT/ELBW group (Yr1): score for EPT/ELBW group relative to NBW group in kindergarten; zSES: change in score corresponding to 1 SD increase in zSES; Months in kindergarten: change in score for each additional month in kindergarten; Yr1 to Yr2, NBW group: change in score from year 1 to year 2 for NBW group; Yr1 to Yr3, NBW group: change in score from year 1 to year 3 for NBW group; Additional Yr1 to Yr2, EPT/ELBW group: change in score from year 1 to year 2 for EPT/ELBW group relative to corresponding change for NBW group; Additional Yr1 to Yr3, EPT/ELBW group: change in score from year 1 to year 3 for EPT/ELBW group relative to corresponding change for NBW group; ADHD symptoms: change in score with increase of 1 symptom; Additional Yr1 to Yr2 with ADHD symptoms: change in score from year 1 to year 2 with increase of 1 symptom; Additional Yr1 to Yr3 with ADHD symptoms: change in score from year 1 to year 3 with increase of 1 symptom.

* $p < .0125$ (Bonferroni Corrected p)