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Mini Tandon

Washington University School of Medicine

Xuemei Si

Washington University School of Medicine

Andy Belden

Washington University School of Medicine

Joan Luby

Washington University School of Medicine

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Attention-Deficit/Hyperactivity Disorder in Preschool Children: An Investigation of Validation Based on Visual Attention Performance

Mini Tandon, D.O., Xuemei Si, M.S., M.P.H., Andy Belden, Ph.D., and Joan Luby, M.D.

Abstract

Objectives: The present study compared the performance of preschoolers who met *Diagnostic and Statistical Manual of Mental Disorders*, 4th edition (DSM-IV) criteria for attention-deficit/hyperactivity disorder (ADHD) to those who did not meet these criteria on a test of visual attention. The aim was to investigate whether attentional impairments in preschoolers with DSM-IV ADHD could be detected, informing the nosology of preschool ADHD.

Methods: A demographically diverse sample of $n = 304$ preschoolers, aged 3.0–5.11 years, was separated into two diagnostic groups: Those who met DSM-IV ADHD criteria and those who did not. Subtypes of ADHD were also examined. Parametric and nonparametric analyses were used to examine performance scores on accuracy, including errors of omission and commission. The sample was stratified into 3-, 4-, and 5-year-old age groups.

Results: Overall ADHD but not subtype-specific ADHD was associated with poor performance accuracy in the 4-year-old age group after controlling for gender and age.

Conclusions: Attentional impairments detected only in the 4-year-old age group suggest that DSM-IV ADHD criteria are useful and valid at this age. Study findings suggest modification to the DSM criteria may be needed for children younger than 4 and that further investigation of this issue using performance-based measures is now warranted.

Introduction

WHETHER ATTENTION-DEFICIT/HYPERACTIVITY DISORDER (ADHD), as defined by the *Diagnostic and Statistical Manual of Mental Disorders*, 4th edition (DSM-IV) (American Psychiatric Association 1994) can manifest in preschool children has been the focus of only a few empirical investigations to date (Sonuga-Barke et al. 2003; Connor 2002; Egger et al. 2006b). Furthermore, many of the existing empirical findings have relied on measures designed for older children, such as the Diagnostic Interview Schedule for Children (DISC) (Shaffer et al. 2000), whereas others have relied on rating scales with inherent subjectivity such as the Conners' Rating Scales (Goyette et al. 1978). Although the Conners' scales have demonstrated modest interrater agreement between teacher and parent ($r = 0.46$ to 0.59), most psychometrics are based on predominantly older samples (DuPaul 1991; Conners et al. 1998). Notwithstanding these methodological limitations, both longitudinal stability of diagnosis over 3–4 years as well as functional impairment have been demonstrated in preschoolers with ADHD in several prior studies (e.g., Campbell et al. 1986; Lavigne et al. 1998; DuPaul et al. 2001; Lahey et al. 2004). ADHD has been well studied in school-aged samples over the last 20 years, but the validity of

the current DSM-IV definition of ADHD has not been well established for preschool-aged children. This may be related in large part to the lack of consideration to age-related, developmentally sensitive changes in symptom manifestations in the current DSM-IV definition. More recently, for example, a review of the design of the largest multisite treatment study of preschoolers with ADHD to date, the Preschool ADHD Treatment Study (PATS) was published. The authors reported the use of high-severity inclusion criteria to account for the concern that DSM-IV ADHD criteria had questionable diagnostic validity in preschool-aged children (Kollins et al. 2006).

ADHD in school-aged children

A total of 3–10% of school-aged children are estimated to have DSM-IV ADHD (American Psychiatric Association 1994; Milberger et al. 1995; Goldman et al. 1998; Rappley 2005). Converging evidence indicates school-aged children with any subtype of ADHD are more impaired socially, academically, and overall than their peers (Nolan et al. 2001; Wilens et al. 2002). It is well supported that ADHD in school-aged children is a serious and impairing disorder that can be safely and effectively remediated when appropriately diagnosed and treated. (MTA Cooperative Group 2004; Rappley 2005).

DSM-IV requires that some symptoms of ADHD must appear prior to age 7 (American Psychiatric Association 1994) for diagnostic criteria to be met. Despite this prerequisite, to date few clear descriptions of age-adjusted symptom manifestations in preschoolers are available. This noteworthy discrepancy underscores the importance of examining the age-appropriate symptom manifestations of ADHD in the preschool period.

Normative attention development

Prior to examining clinical inattention in preschoolers, it is essential to consider what is currently known regarding the normative development of attention. The term "attention" has been used interchangeably with "concentration" to denote use of brain resources toward a specified task (Bjorkland 2000). Several aspects of attention are worth examining; the most pertinent include duration of attention, or ability to sustain attention (also referred to as vigilance), previously defined as "continuous processing of information over time and the specificity of attention including ability to disengage, change focus, and selectively attend" (Halperin 1991). Some degree of distractibility can be normative and functionally necessary; to be severely distractible is impairing, maladaptive, and of clinical concern (Ruff and Capozzoli 2003). Studies examining the development of attentional capacities in young children have demonstrated that the ability to sustain attention improves with age and that attentional aptitude in toddlers may predict attentional capacities in early childhood (Ruff and Lawson 1990; Bjorkland 2000).

Ruff and Capozzoli (2003) report that distractibility decreases over time, but most rapidly in the first 6 months of life. The ability to attend to stimuli selectively is well developed by the age of 4 months. This selective focus likely serves other key developmental trajectories, including socioemotional milestones (Ruff and Capozzoli 2003). More recently, evidence that ADHD symptoms decrease with maturation of the central nervous system in later childhood and mid-adolescence has been provided (Shaw et al. 2007). This longitudinal change in neurobiological development warrants careful observation given that some seemingly affected individuals may indeed outgrow reported symptoms (Connor 2002). In keeping with this model, recently it was reported that children with ADHD develop peak cortical thickness later than those without ADHD, particularly in brain regions associated with attention (Shaw et al. 2007).

Of particular importance, attention to structured tasks may be different than self-directed play activity or physical activity. Observation of the preschooler completing multiple types of activities during a clinical assessment will lead to a more comprehensive understanding of attention, and a thorough history will help to establish context specificity (Zeanah 2000; Carter et al. 2004). Context specificity is a key consideration in all preschool psychopathology, and, notably, the current DSM-IV ADHD criteria for all ages require impairment in at least two settings (American Psychiatric Association 1994).

ADHD as it manifests in preschoolers

The DSM-IV criteria for ADHD, including the domains of hyperactivity, impulsivity, and inattention, are more difficult to ascertain and characterize in preschoolers. In general, comparison of direct observation and parent informants re-

porting on externalizing symptoms in preschool-aged children, such as those that characterize ADHD, have been found to have modest correlations (Kagan 1998; Gardner 2000). However, a multisite, multiinformant outcome study demonstrated modest correlations between mothers' and teachers' reports, even for inattention and impulsivity in both clinical and community samples of 4- to 8-year-old children (Ablow et al. 1999). Furthermore, Luby et al. (2007) have provided data suggesting that self-report of externalizing symptoms is even less reliable than internalizing symptoms in this age group. Parent report of symptoms may be diminished by the tendency to normalize these behaviors as characteristic of the preschool period (Wakschlag et al. 2005; Maniadaki et al. 2006; Steinhoff et al. 2006). Similarly, teachers may be hesitant to report these symptoms in such young children, based on the expectation that preschoolers have wide variation in developmental skills and will likely outgrow the behaviors (Carter et al. 2004; Steinhoff et al. 2006). Several studies suggest parents endorse ADHD symptoms more readily than teachers of preschool children (Phillips et al. 2002; Posner et al. 2007).

Given these reporter discrepancies and the fact that informants may tend to normalize symptoms of ADHD during the preschool period as developmental extremes (i.e., problematic but something they will "grow out of") without clinical significance, it would be helpful to consider which symptoms of ADHD are found frequently in the general preschool population. For example, Egger et al. (2006b) reported on data from a community-based sample demonstrating that 50% of parents of preschoolers without ADHD reported the symptoms of interrupts/intrudes. It was notable that this symptom was reported at a rate of 100% among preschoolers with ADHD. Other studies have also examined the prevalence of particular symptoms in preschoolers. In examining age-appropriate manifestations of ADHD in the preschool period, Smidts and Oosterlaan (2007) found difficulty playing quietly (54.6% of total symptom prevalence), talks excessively (51.6%), and difficulty engaging in tasks requiring sustained mental effort (50.1%) to be the most frequently endorsed by parents in a community-based sample. Kadesjo et al. (2001) found the best discriminators of ADHD to be symptoms of difficulty sustaining attention and easily distracted in Swedish preschoolers ages 3–7 compared to healthy controls. In contrast to the former study, Kadesjo reported that talks excessively was the worst discriminator, occurring frequently in preschoolers without ADHD. This discrepancy also raises the interesting issue of whether there are cultural differences in symptom manifestations of ADHD. Based on the commonly reported symptom of difficulty sustaining attention as one of the most specific markers in preschoolers with ADHD, greater focus on whether this impairment can be reliably detected in preschoolers with ADHD is needed.

In an epidemiological investigation that focused only on the preschool-aged group (2–5 years old), Egger et al. (2006b) reported prevalence of DSM-IV ADHD as 2.0–7.9%. Most of the ADHD symptoms occurred in less than 10% of preschoolers, suggesting that ADHD symptoms are neither normative nor common during this period (Egger et al. 2006b). Explanations for discrepancies in prevalence of preschool ADHD have included definitional issues (such as analysis of specific symptoms without regard to total symptom count recommended by DSM-IV, whether impairment is included in the diagnostic algorithm as required by DSM-IV)

and sampling issues (differences between referred vs. non-referred samples, or the combining of preschool and school-aged children into one study sample) (Egger et al. 2006b).

Importance of early identification

Although caution is warranted in the extrapolation of empirical findings in school-aged children to preschoolers, these studies provide valuable empirical insight into very-early-onset ADHD. Emerging literature in school-aged children suggests those with untreated ADHD may have an earlier age of onset of substance abuse. These children may also transition more quickly from substance abuse to dependence than healthy same-aged peers (Biederman et al. 1997). Children with ADHD have also been found to be more accident prone and at risk for physical injury (Lam 2002). Social impairments have also been detected (DuPaul et al. 2001). On the basis of prior findings that often illustrate multiple serious consequences of untreated ADHD and related behaviors, it is necessary to clarify the nosology of ADHD in the preschool period of development to facilitate earlier identification and intervention. Early intervention has been shown to improve prognoses of a number of childhood disorders, including in disruptive and autistic spectrum disorders (Fenske et al. 1985; Eyberg et al. 1995). This possible window of opportunity in the preschool years warrants early and accurate diagnosis given the potential for better prognosis. The general lack of consideration to age-adjusted symptom criteria for preschoolers in the DSM-IV along with the challenges of the subjectivity of and discrepancies between parent and teacher informants warrant further studies of the diagnostic criteria for ADHD in this very young group. Studies that make use of objective performance-based measures would be particularly elucidating for further clarification of the nosology of early onset ADHD.

In summary, the extant literature includes studies of preschool ADHD that use parent, teacher, and child report of symptoms. Given the subjectivity of informants, the low correlations found between informants, and the related risk of bias or misattribution, it is necessary to increase the use of objective markers of inattention, such as performance-based measures, to investigate the validity of the diagnosis during the preschool period (Maniadaki et al. 2006). Few studies to date have examined performance-based measures of attention in preschool populations. Challenges in development and utility of performance tasks to measure attention in preschoolers have included use of age-appropriate stimuli, task duration, rate of stimuli presentation, and lack of distractors on the task (Herman et al. 1980; Harper and Ottinger 1992; Corkum and Siegel 1993; Prather et al. 1995). Some exceptions have included the Children's Continuous Performance Test (C-CPT) (Kerns and Rondeau 1998), a shorter, modified, age-appropriate version of the Continuous Performance Test initially developed by Rosvold et al. (1956). In general, there is a dearth of such performance-based measures validated in preschoolers. In a review of neuropsychology measures used in younger children, Heffelfinger and Koop (2008), underscore the utility of the Developmental Neuropsychological Assessment (NEPSY) (Korkman et al. 1998) as one of few measures that is well designed to examine executive function in children as young as 3 years of age.

The present study aimed to investigate the question of whether objective impairments in attentional performance could be

detected in preschool children who met DSM-IV criteria for ADHD. This type of investigation contributes to a currently limited body of empirical literature that addresses whether or not objective impairments exist in preschoolers aged 3.0 to 5.11 years who are diagnosed with the unmodified DSM-IV criteria.

It was hypothesized that: (1) Preschoolers diagnosed with DSM-IV ADHD would have decreased overall accuracy scores in this visual attention performance test, (2) that the preschoolers with ADHD-inattentive subtype would have greater omission errors than the other subtypes, and (3) those with ADHD-hyperactive/impulsive subtype would have greater commission errors than the other subtypes.

Methods

Subjects

A sample of $n = 304$ preschoolers, aged 3–5.11 years, was ascertained from multiple sites throughout the greater metropolitan St. Louis area. To obtain an ethnically and socioeconomically diverse sample, primary care, pediatric clinics, and preschools/daycares available to the overall community served as recruitment sites. These sites were selected at random using a geographically stratified method (see Luby et al. 2009, for further details). The group was oversampled for depressive disorders on the basis of parent responses on a previously validated screening checklist, the Preschool Feelings Checklist (Luby et al. 1999; Luby et al. 2004); however, children with disruptive symptoms were also sought and included as a psychiatric comparison group. Preschoolers with chronic medical or neurological problems, mental retardation, or autistic spectrum disorders were excluded. The DSM-IV diagnoses were based on parent report on the Preschool Age Psychiatric Assessment (PAPA) (Egger et al. 1999), an age-appropriate, semistructured interview with established test-retest reliability and validity for preschoolers (Egger et al. 2006a). The final diagnoses were derived using computerized DSM-IV-based algorithms. Information about the use of psychotropic medication in the study sample was obtained from the PAPA as well as from parent reports on the Health and Behavior Questionnaire (HBQ) (Armstrong and Goldstein 2003).

For the following analyses, preschoolers who met the diagnosis of ADHD regardless of co-morbidity were in the "ADHD" group ($n = 48$) and the comparison group consisted of those with "no-ADHD" ($n = 242$), which included both healthy preschoolers ($n = 143$) (no DSM-IV diagnoses) as well as those meeting criteria for other axis-I DSM-IV diagnoses ($n = 99$), which included major depressive disorder (MDD), generalized anxiety disorder (GAD), separation anxiety disorder (SAD), posttraumatic stress disorder (PTSD), bipolar disorder (BP), oppositional defiant disorder (ODD), and/or conduct disorder (CD). In addition, $n = 14$ participants who failed to meet criteria for ADHD were excluded from the analyses based on ongoing treatment with a stimulant ($n = 10$) as were those having the diagnosis of only BP I ($n = 2$) and those with extensive missing data ($n = 2$). For additional secondary analyses, participants were also separated into specific subtypes of DSM-IV ADHD using a computer algorithm. These included Inattentive (IA; $n = 7$) preschoolers who had a predominance of inattentive symptoms, Hyperactive/Impulsive (H/I; $n = 21$) preschoolers who had a predominance of hyperactive-impulsive symptoms, and Combined (C; $n = 20$) preschoolers who met both inattentive

and hyperactive-impulsive criteria. Due to the central importance of chronological age in attentional performance, participants of all ages were analyzed simultaneously as well as by age stratification into 3-, 4-, and 5-year-old age groups.

Measures

Performance-based measures were administered to the child in the laboratory as a part of a larger developmental and behavioral assessment. Measures of attention included a visual attention task and a sensorimotor function task of fingertip tapping from the NEPSY (Korkman et al. 1998), which is a validated and standardized neuropsychological instrument for children 3–12 years of age, widely used in psychological assessments. It allows assessment of five cognitive domains, including Attention/Executive Function, Sensorimotor Function, Visuospatial Processing, Memory and Learning, and Language, within which subtests may be utilized independently. A visual attention subtest (from the Attention/Executive Function Domain) in which the preschooler is assessed for accuracy and speed for marking age-based visual targets (bunnies and cats for ages 3–4; cats and faces for ages 5–12) in a 6-minute maximum time span was also administered. Accuracy was determined by the number of correctly marked items and by subtracting incorrectly marked items. Speed was measured as time to completion. Additional analyses were performed using only a specified target from the NEPSY (cat), given the continuity of this item to all 3, 4, and 5 year olds. This methodology was used previously by Heffelfinger and Koop (2008).

The authors of the NEPSY report that the relatively lower reliability coefficients of the Attention/Executive Domain composite scores in preschoolers ages 3 ($r = 0.69$) and 4 ($r = 0.71$) compared to those 5 years of age ($r = 0.85$) are supported by the known variability of performance in the 3- to 4-year-old age group specific to this domain. The overall reliability scores of other NEPSY composite domains for 3 to 4 year olds are higher ($r = 0.88$ – 0.91). The NEPSY also reports on discriminant validity of the test to detect performance differences in a group with ADHD ($n = 50$) and matched controls in the Attention/Executive Domain to be significant ($t = -3.32, p = 0.002$).

Second, from the Sensorimotor Domain, the subtest of fingertip tapping was used to assess motor speed and finger dexterity using both repetitive and sequential tapping. Time to complete 32 repetitive finger taps was recorded allowing for a 60-second time limit. Time to complete 8 sequential finger taps was recorded in a 90-second maximum time span.

Outcome measures included performance on the visual attention task (speed and accuracy) and fingertip tapping (motor speed and finger dexterity). Accuracy was specifically examined for errors of omission (number of missed targets) and commission (number of incorrectly marked targets) thought to be associated with inattention and impulsivity, respectively (e.g., Barkley 1991; Inoue et al. 1998).

Chi-squared tests and independent sample *t*-tests were used to compare demographic characteristics between ADHD and no ADHD groups (see Table 2). A *t*-test was also used to test for differences in total accuracy scores between ADHD and no-ADHD groups. Simple linear regression and/or *t*-tests were used to identify covariates for total accuracy from all other DSM-IV diagnoses and demographic variables. Univariate analysis of covariance (ANCOVA) was used to examine the association between ADHD and total accuracy scores after controlling covariates. The same analyses were performed in the age-stratified sample. A multivariate analysis of covariance (MANCOVA) was used to examine simultaneously all visual attention performance accuracy scores (including total accuracy and commission and omission errors) for a specified target (cat). ANCOVA was used to examine the association between ADHD and the specified target visual attention total accuracy score after controlling for age in months.

Due to the small sample size and nonnormatively distributed data, nonparametric methods were conducted to compare all visual attention test scores for the specified target among ADHD subtypes (Inattentive ADHD, IA; Hyper/Impulsive ADHD, HI; and Combined ADHD, C) and healthy groups. Next, MANCOVAs were used to examine the association between all visual attention performance scores (both raw and ranked scores) and any significantly associated subtype of ADHD after controlling for other potential factors. SPSS 15.0 was used for all analyses (Table 1).

Results

Demographic differences between study groups

There were no significant differences between the ADHD group and no-ADHD group in relation to preschoolers' gender, age, and ethnicity. However, results indicated that parent marital status ($\chi^2 = 10.42, df = 4, p = 0.034$) and family income ($\chi^2 = 15.13, df = 3, p = 0.002$) were significantly different between the ADHD group and no-ADHD group (Table 2). Specifically, a significantly larger proportion of preschoolers who met criteria for ADHD came from single-parent and/or

TABLE 1. STATISTICAL ANALYSES STEPS

1. Compared total accuracy scores (cat/bunny [for 3 and 4 year olds], cat/face [for 5 year olds]) between ADHD and no ADHD, controlling for covariates
2. Used same analyses as step 1 with age-stratified sample (3-, 4-, and 5-year-old groups)
3. Used specified (cat) target only, compared total accuracy scores, commission and omission errors between ADHD and no ADHD, controlling for covariates
4. Used same analyses as step 3 with age-stratified sample (3-, 4-, and 5-year-old groups)
5. Used entire sample and specified (cat) target, compared total accuracy scores, commission and omission errors among subtypes of ADHD (IA, HI, C) and healthy subjects, and among ADHD subtypes

Abbreviations: ADHD = Attention-deficit/hyperactivity disorder; IA = Inattentive ADHD; HI = Hyper/Impulsive ADHD; C = Combined ADHD.

TABLE 2. DEMOGRAPHIC CHARACTERISTICS OF THE STUDY SAMPLE

	ADHD (n = 48)	No-ADHD (n = 242)	χ^2	p value
Gender			2.50	0.114
Male	60% (29)	48% (116)		
Female	40% (19)	52% (126)		
Age in years			5.76	0.056
3	44% (21)	30% (72)		
4	27% (13)	45% (109)		
5	29% (14)	25% (61)		
Ethnicity			3.43	0.180
White	44% (21)	57% (138)		
Black	37% (18)	31% (75)		
Other	19% (9)	12% (28)		
Parent marital status			10.42	0.034
Married	38% (18)	61% (144)		
Separated	2% (1)	2% (6)		
Divorced	10% (5)	7% (17)		
Widowed	0	1% (1)		
Never married	50% (24)	29% (67)		
Family income (n = 269) ^a			15.13	0.002
0 to \$20,000	37% (18)	19% (42)		
\$20,001 to \$40,000	27% (13)	17% (38)		
\$40,001 to \$60,000	17% (8)	18% (40)		
Over \$60,000	19% (9)	46% (101)		

^aFamily income was categorized into four groups.
Abbreviation: ADHD = Attention-deficit/hyperactivity disorder.

lower-income family environments compared to no-ADHD same-aged peers. No other demographic differences between these two groups were found.

Total accuracy scores for ADHD versus no-ADHD

Total accuracy raw scores for attentional performance were significantly different in the ADHD group compared to the no-ADHD group. No-ADHD preschoolers performed better ($M = 16.12, SD = 22.03$) than ADHD preschoolers ($M = 8.94, SD = 22.40$) ($t = 2.04, df = 284, p = 0.042$). Findings indicated that females had significantly higher scores of accuracy ($M = 17.74, SD = 22.45$) than males ($M = 12.18, SD = 21.71$) ($t = 2.13, df = 284, p = 0.034$). Older preschoolers also had significantly higher scores of accuracy ($t = 2.64, df = 284, p = 0.009$) than younger preschoolers. Higher family income was associated with higher performance accuracy ($t = 3.08, df = 264, p = 0.002$). Ethnicity and parental marital status were not associated with performance accuracy. There was no association of other co-morbid DSM-IV psychiatric disorders to the outcome variable of performance accuracy on the visual attention test. After controlling for age (in months), gender, and family income using ANCOVA, the diagnosis of ADHD in the sample overall was not associated with total accuracy scores, contrary to the first hypothesis. Speed was not found to be significantly associated with DSM-IV ADHD in either the visual attention or the fingertip-tapping test.

To address age differences in objective performance measures of ADHD symptoms, preschoolers were further stratified into 3-, 4-, and 5-year-old age groups (see Table 1). DSM-IV ADHD was significantly associated with poorer performance accuracy on the visual attention test only among the 4-year-old age group ($t = -2.56, df = 120, p = 0.012$; the nonparametric Mann-Whitney U-test showed a similar result:

$z = -2.13, p = 0.033$; Fig. 1). Age in months and gender were also associated with performance accuracy in the 4-year-old age group. After controlling for gender and age in months, preschoolers in the 4-year-old age group had performance accuracy scores that were inversely associated with diagnosis of DSM-IV ADHD ($t = -2.62, df = 118, p = 0.010$); the same results held when we used ranked performance accuracy scores.

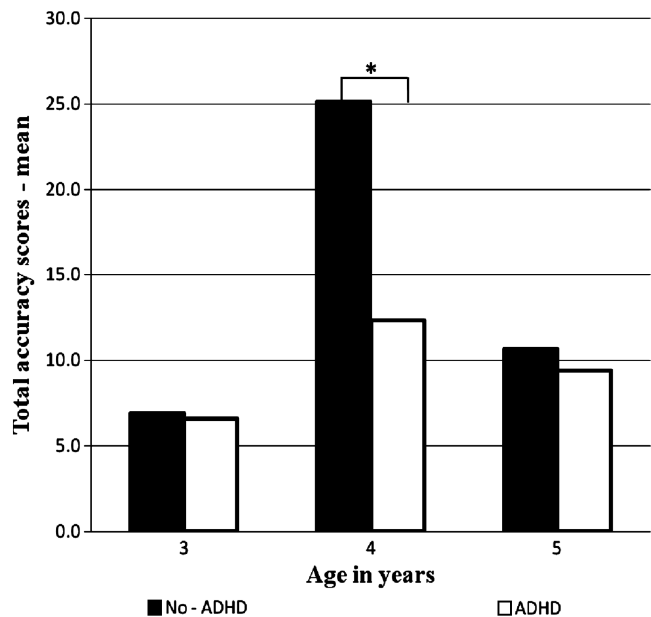


FIG. 1. Mean total accuracy scores for no-ADHD subjects and ADHD subjects by age groups. (*) $p < 0.05$.

The 5-year-old age group was examined further for accuracy differences by dividing the cohort in half so that children 5.0–5.5 years old ($n = 40$) were in the younger group and children 5.6–5.11 years old ($n = 35$) were in the older group. Despite this separation, there was no association of ADHD with performance accuracy scores within each of these two smaller subgroups. However, it should be noted that the ADHD groups sizes were very small ($n = 8$ in younger 5-year-old subgroup; $n = 6$ in older 5-year-old subgroup).

NEPSY visual attention test for subtypes of ADHD

Additional analyses were performed using only one visual stimulus (the cat test target item) given the overlap of this item to all 3, 4, and 5 year olds. When using this target from the visual attention performance test for the entire sample, preschoolers in the ADHD group had lower total accuracy scores ($t = -2.03$, $df = 284$, $p = 0.043$). However, the ADHD diagnosis was not associated with total accuracy scores after controlling for age (in months). There were no significant differences between the ADHD and no-ADHD groups with regard to commission and omission errors. Additional analyses of ADHD subtypes indicated a significant difference for target commission errors (Kruskal–Wallis test $p = 0.026$) and a p value that approached significance in relation to target total accuracy scores (Kruskal–Wallis test $p = 0.053$) among three ADHD subtypes and healthy groups. The Mann–Whitney U-test indicated that HI-ADHD subjects had significantly lower accuracy scores ($p = 0.023$) and higher commission errors ($p = 0.013$) than healthy subjects; however, using MANCOVA analyses for total accuracy scores and commission error scores, HI-ADHD lost its significance after controlling for age in months and gender. The same results held when we used ranked scores. Nonparametric methods were also used to compare visual attention test scores among three ADHD subtypes. No other significant associations were found after examining specific symptoms of the subtypes of ADHD with commission/omission errors.

Discussion

Objective impairments in performance on the visual attention task were found in a subgroup of preschoolers, aged 4.0–4.11 years with DSM-IV ADHD. These findings provide external validation for the diagnosis in this age group. These findings suggest that, current DSM-IV criteria for ADHD appear to be age appropriate to identify preschoolers with objectively measured impairments in attention as young as 4.0.

However, impairments in performance accuracy on this visual attention test were not detected in either 3 or 5 year olds. Several reasons for these discrepant age findings should be considered. First, is the possibility that the accuracy test used was more sensitive for 4 year olds. The test placed slightly different discriminatory demands on the 5-year-old age group, in which an array of target faces among distractor faces were to be marked instead of the same task for 3 and 4 year olds, in which target items (bunnies) among an array of different items (not bunnies) were to be marked. This likely made the test more challenging for many 5 year olds and potentially less useful for detecting the hypothesized differences. The authors of the NEPSY also report that the test may not always be appropriate to cognitive level because many

neuropsychological tests currently used with children were originally developed for adults to assess cognition and functional impairment. Unfortunately, there remains a lack of available neuropsychological assessment tests both clinically appropriate for children less than 6 years of age and domain-specific for attention as in the NEPSY (Heffelfinger and Koop, 2008). The development of such measures is needed for future study.

On the basis of the available studies of ADHD that have included 5-year-old children and have shown longitudinal stability of symptoms, the failure to detect impairments in attention on the NEPSY in this study would seem to be a measurement failure rather than a failure of the DSM-IV criteria. This failure to detect differences in performance accuracy among those children with ADHD compared to those without ADHD was noted even when the 5-year-old group was divided into younger and older subgroups, suggesting the difficulty of the task even among the older 5-year-old subgroup. However, it should be noted that the ADHD group sizes were very small. Direct investigations of this issue are still needed in 5-year-old children who meet DSM-IV ADHD criteria. Future investigation of the ability of the measure to detect any performance accuracy differences associated with ADHD in 6 year olds would help inform further study.

Failure of the DSM-IV criteria for ADHD in 3 year olds

In addition to the failure to detect differences in attention among the 5-year-old age group, the study found no differences in performance among DSM-IV ADHD and no-ADHD preschoolers in the 3-year-old age group. This failure to detect differences in attention in the 3-year-old group, who received the identical test as the 4-year-old group, a test with well-established reliability and validity for use in this age group, raises the question of whether the current DSM-IV criteria can be appropriately applied to this very young group without developmental modification. For example, criteria such as “makes careless mistakes” may not apply to a 3 year old who is rarely placed in a situation in which this kind of functioning is required. Furthermore, “often has difficulties organizing tasks” or “often loses things” may be problematic for the same reason, making these criteria less applicable and having low face validity for this very young cohort. These findings suggest that modification to the current DSM-IV ADHD criteria may be needed in children younger than 4.0 years old. The need for careful clinical assessment of this very young group, including the importance of ruling out normative inattention in 3 year olds, cannot be overstated.

The notion that current DSM-IV criteria may need modification for very young children is also suggested by the inclusion criteria for the PATS study, the largest multisite treatment study of preschool ADHD to date (Kollins et al. 2006), which included subjects ages 3.0–5.5. The authors report modification of methods to ensure that preschoolers with developmentally appropriate but increased levels of inattention, hyperactivity, or impulsivity were not included by requiring multiple informants, and use of structured and clinician interview. Furthermore, they changed the duration of impairment criteria from 6 (DSM-IV) to 9 months, requiring a moderate to high severity score on the Children’s Global Assessment Scale (C-GAS) (Shaffer et al. 1983). Whereas the use of these more stringent criteria increased the likelihood of

capturing the most impaired preschoolers for purposes of the treatment study, preschoolers who may have had clinically significant ADHD may have been missed. Which specific symptoms of the DSM-IV criteria for ADHD would need modification for use in 3.0-year-old preschoolers remains largely unexamined in the extant literature. Alternatively, the failure to detect attentional differences among the 3-year-old age group in the current study could be related to small sample size, and the possibility of a Type II error cannot be ruled out. Investigation of attentional performance in 3 year olds who meet DSM-IV ADHD criteria using a larger sample is now needed.

Inadequacy of subtypes of ADHD for use in preschoolers

No differences in performance accuracy between inattentive and impulsive subtypes of ADHD were found. More specifically, previous performance-based studies of attention in older children have analyzed accuracy as errors of omission and commission, thought to correlate to inattentive and impulsive symptoms respectively (Barkley 1991). However, similar to findings from the current study, several of these investigations in school-aged children also found that these errors were nonspecific across symptom domains (Barkley 1991; Chhabildas et al. 2001; Epstein et al. 2003). The lack of association among subtypes of ADHD and specific error types also calls into question more broadly the conventional use of subtyping in childhood ADHD in general as well as among preschoolers. Again, the possibility of a Type II error could account for the lack of subtype differences as well, and future investigations using a larger sample could better inform future nosology. Along these lines, a recent longitudinal study in older children reported general instability of specific subtypes of DSM-IV ADHD diagnosis and called for the need for more developmentally appropriate criteria for DSM-V (Lahey et al. 2005; Todd et al. 2008). Therefore, on the basis of several lines of evidence, the need for further investigation of developmentally specific diagnostic criteria for ADHD and subtypes in younger children is now needed.

Limitations

There are several limitations to the current study in addition to concerns related to the potential lack of power to identify the hypothesized effects and the limitations of the measure of executive function. As previously discussed, the relatively small size of the preschool ADHD sample stratified by age is a limitation. Also, study findings may have limited generalizability based on the nature of the sample that was oversampled for mood symptoms (the main aim of the study). However, the sampling feature makes the significant findings in the 4-year-old age group even more robust because they were compared to a group that also included those with psychiatric disorders that could impair attention. Furthermore, the present study did not examine differences in teacher and parent report or another performance-based test, such as the CPT, which may be useful. This comparison of reporter bias of symptom report compared to objective outcomes on performance tests was outside the scope of the present study but certainly warrants future study.

Although there are no known causal risk factors for ADHD, the question of why a larger proportion of children

with ADHD came from lower-income families and single-parent households compared to those with no ADHD in this study merits consideration. Similar findings have also been reported in prior studies (Nichols and Chen 1981; Palfrey et al. 1985). Additional variables such as parental educational level, maternal age at delivery, parental ADHD diagnostic status, child's birthweight, and *in utero* alcohol or smoking exposure, all potential contributors to ADHD diagnosis in the child, could further elucidate this finding but were not available in the current study (Barkley 2006). It could be speculated that mothers in lower-income families and single-parent households experience more stressors that may increase the risks of perinatal complications, which may confer greater neurological risk *in utero* for ADHD (Claycomb et al. 2004). Furthermore, these complications may be heightened by early age at delivery and lower parental educational level often associated with lower family income (Claycomb et al. 2004). Indirect association with low birth weight has also been suggested to be three-fold higher in those with ADHD compared to those without ADHD (Mick et al. 2002). However, other studies did not find support for higher incidence of complications among those with ADHD (Barkley et al. 1990). Conversely, ADHD has been shown to be highly heritable, with a 57% risk to a child with one parent with ADHD (Biederman et al. 1995). As demonstrated in other Axis I disorders, adult ADHD may be associated with "downward social drift" contributing indirectly to lower parental educational level and income (Barkley 2006). These associations were outside the scope of this study but certainly warrant further investigation.

Clinical implications

The use of performance-based measures to detect objective attentional impairments in preschoolers with ADHD has been rare. The need for such methods of external validation is particularly evident for preschoolers under the age of 4.0, as supported by the current study findings. As supported by prior literature, the consideration of modified criteria in this very young age group may be indicated. Given the lack of age-sensitive criteria, clinicians would need to continue to rely on updated practice guidelines for the treatment of ADHD in preschoolers. The dearth of empirical research in this area has led to these parameters being based largely on clinical consensus. They suggest use of parent management training prior to stimulant treatment given both the uncertainty of diagnosis and unknown impact of medications on brain development at such an early age. Furthermore, some consensus groups and others have suggested that medication treatment should be reserved only for severely impaired preschoolers refractory to psychosocial interventions (Sonuga-Barke et al. 2003; Gleason et al. 2007).

Given that the interpretability of DSM-IV-diagnosed ADHD in preschoolers between the ages of 3.0 and 3.11 remains questionable, the current study supports caution in the use of medication in preschoolers overall, but particularly in those preschoolers younger than age 4.0. While the PATS helped to inform the safe use of methylphenidate in preschoolers, it should be noted that DSM-IV criteria in PATS were modified to include only preschoolers with a more chronic and severe form of the disorder. Therefore, preschoolers meeting current unmodified DSM-IV criteria as

used in the present study require continued clinical judgment and caution, particularly those younger than 4.0 years of age.

Whereas the findings of this study suggest questionable application of standard DSM-IV ADHD diagnosis in those children younger than age 4.0, the impairment and implications of early psychopathology that may exist in this very young age group remain an important clinical issue for further investigation. Early but careful clinical assessment is still warranted, given that the mean age of onset of ADHD symptoms has been reported to be between 3 and 5 years (Barkley 2006). Early clinical detection of symptoms with longitudinal follow up may inform persistence or chronicity of later ADHD when treatment may be more feasible. For example, children whose symptoms persisted from age 3 to 4 have been shown to be more likely challenged with conduct problems and impairing hyperactivity by ages 6 and 9 (Campbell 1990). Similar results are supported in other studies (Earls and Jung 1987; Barkley et al. 2002). The need for more performance measures that may facilitate early and accurate diagnosis of ADHD in clinical settings cannot be overemphasized.

Disclosures

The authors have no conflicts of interest or financial ties to disclose.

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Address reprint requests to:

Dr. Mini Tandon

Department of Psychiatry

Washington University School of Medicine

660 South Euclid

St. Louis, MO 63110

E-mail: tandonm@psychiatry.wustl.edu