Classroom Observations Of Attention-Deficit/Hyperactivity Disorder: Patterns And Characteristics Of Attention Over Time

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CLASSROOM OBSERVATIONS
OF ATTENTION-DEFICIT/HYPERACTIVITY DISORDER: PATTERNS AND
CHARACTERISTICS OF ATTENTION OVER TIME

by

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B.S. FLORIDA STATE UNIVERSITY, 1998

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ABSTRACT

Investigated differences in attentional processes between children diagnosed with Attention-Deficit/Hyperactivity Disorder (ADHD) and their classroom peers. Models of attention gleaned from laboratory experiments provided a theoretical structure for hypothesizing between-group attentional differences. Seventy-five children with ADHD and 36 normal control children were observed in their regular classrooms over a 1-week time interval. Explication of between-group differences revealed that children with ADHD were approximately 21% less attentive on average. Both groups exhibited an accelerating-decelerating pattern of attention over time, however, children with ADHD cycled at a rate twice that of same-aged peers. Six variables derived from observed attention were examined for diagnostic utility using logistical regression, odds ratios, total predictive value, and receiver operating characteristics. Implications of these findings are discussed.
ACKNOWLEDGMENTS

Thanks to Dr. Mark Rapport, Dr. Jack McGuire and, Dr. Valerie Sims, as well as the University of Central Florida.
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Attention-deficit hyperactivity disorder (ADHD) is a complex and chronic disorder of brain, behavior, and development whose behavioral and cognitive consequences affect multiple areas of functioning both within and across settings. The attention-deficit feature of the disorder has undergone extensive empirical scrutiny following the seminal work by Douglas and colleagues (Douglas, 1972; Sykes, Douglas, Weiss, & Minde, 1971). Extant evidence suggests that children with ADHD experience difficulties focusing and maintaining their attention, and that these difficulties are apparent on a wide range of tasks and in most settings. For example, referral complaints often include reports that children with ADHD tend to pay less attention during instruction and independent work periods than their peers (Abikoff, Gittelman-Klein, & Klein, 1977), fail to consistently complete academically oriented work (Barkley, DuPaul, & McMurray, 1990), and shift from one activity to another at home (DuPaul & Stoner, 2003). These deficiencies are particularly apparent in the context of what might be considered dull, repetitive tasks or activities and those that place greater demands on working memory (Douglas, 1988; Rapport, Chung, Shore, & Isaacs, 2001), yet may be attenuated under conditions that involve novel situations (Power, 1992; Zentall & Meyer, 1987) or frequent reinforcement (Pelham, Milich, & Walker, 1986).

Controlled investigations in clinical laboratories and academic settings support common referral complaints. For example, significant differences are frequently, albeit not always reported between children with ADHD and normal
controls in identifying infrequently occurring stimuli over extended periods of
time as measured by continuous performance tests (for a review, see Rapport,
Chung, Shore, Denny, & Isaacs, 2000). Difficulty initiating and maintaining
attention in academic settings based on teacher ratings (Abikoff, Gittelman, &
Klein, 1980; Cunningham & Siegel, 1987; Schachar, Sandberg, & Rutter, 1986),
direct observations (Abikoff et al., 1977; Kazdin, Esveldt-Dawson, & Loar, 1983;
Roberts, 1990), and expected byproducts of attention such as completed
assignments (DuPaul, Guevremont, & Barkley, 1992) are also consistently
reported in children with ADHD.

Two models hypothesized to account for the attentional problems in children
with ADHD have received equivocal support. According to the decrement model,
children with ADHD are hypothesized to possess normal ability for attending to
stimuli initially, whereas the mechanisms that govern the ability to sustain
attention over time are suspect relative to unaffected peers (Douglas, 1999;
Hooks, Milich, & Lorch, 1994; Seidel & Joschko, 1990). This model predicts no
significant initial differences between children with ADHD and normal controls
on clinic based tasks or when observed in the classroom. Rather, differences in
attention and performance are indicated by a steeper slope in the ADHD relative
to normal control group curves as a function of time, and evidenced by a
significant group by time interaction (Sergeant & van der Meere, 1994). A
graphical illustration of this model is depicted in Figure 1-a. In contrast, the
deficit model proposes that differences in the mechanisms that govern and
regulate attention in normal children and those with ADHD are immediately
apparent but not differentially affected over time (Leung & Connolly, 1994; van
der Meere & Sergeant, 1998). As a result, this model predicts significant initial differences between children with ADHD and normal controls that remain relatively consistent over time as indicated by similarly sloped lines that are highly divergent from the onset. A graphical illustration of this model is depicted in Figure 1-b. A *hybrid* model is also possible, albeit not mentioned in the literature, which combines the central elements of both the decrement and deficit models. This model predicts both an initial deficit and greater decrement over time as indicated by significantly lower scores initially and steeper time course slopes as shown in Figure 1-c.

Extant research supporting the decrement and deficit models is inconsistent and gleaned primarily from clinic-based investigations. For example, a large percentage of clinic-based studies report significant differences between children with ADHD and normal controls across a variety of instruments (for reviews, see Douglas, 1988; Rapport et al., 2000), but only a small sampling of these studies directly assess attention and include experimental parameters relevant to detecting performance decrements over time. A review of these studies reveals that several (Hooks et al., 1994; Schachar, Logan, Wachsmuth, & Chajczdy, 1988; Seidel & Joschko, 1991) but not all (Barkley, Anastopoulos, Guevermont, & Fletcher, 1991; Harper & Ottinger, 1992) report significantly greater decrements over time in children with ADHD relative to normal controls on vigilance tests. When observed, decrements are reported to occur between 10 and 15 minutes following the onset of the task (Hooks et al., 1994; Seidel & Joschko, 1990).
Figure 1. Three Hypothesized Models of Attention. Graphical illustrations of three hypothesized models of attention for children with ADHD: (a) decrement, (b) deficit, and (c) hybrid.
Questions concerning the ecological validity of clinic-based findings pertinent to assessing children with ADHD have been raised in past years (Barkley, 1991; Rapport, DuPaul, Stoner, & Jones, 1986). The central question, however, is not whether the results of laboratory findings can be generalized to field settings, but whether the deficiencies in attention observed under highly controlled laboratory conditions using computerized testing protocols represent the same deficiencies (and by implication, processes) observed in natural settings such as the classroom. For example, do children with ADHD exhibit attention decrements while working in the classroom that are characteristically observed in laboratory settings, or might other models better characterize their attention in this setting? The centrality of this question is highlighted by the fact that most referrals for assessment are initiated owing to behavior and academic concerns in the classroom (DuPaul & Stoner, 2003).

Turning to extant literature that incorporates observation of children in classroom settings reveals highly uniform reports that children with ADHD are more inattentive (i.e., off-task) compared to normal controls (Abikoff et al., 2002; Zentall, 1980). This appears to hold true for observations as brief as 10 minutes (Abikoff et al., 1980; Schachar et al., 1986) and as long as 90 minutes (Klein & Young, 1979), when using simple (Roberts, 1990) and highly complex classroom coding schemas (Abikoff et al., 2002; Cunningham & Siegel, 1987; Klein & Young, 1979), and for younger (Schachar et al., 1986) and older children (Jacob, O’Leary, & Rosenblad, 1978). Differences in rates of directly observed attentive behavior between children with ADHD and normal controls vary between 9.4% (Abikoff & Gittelman, 1984) and 63% (Jacob et al., 1978), with a median of
29.7% based on a recent review of 24 controlled outcome studies (Kofler et al., 2004). It is not possible to discern from these studies, however, whether the observed attention deficits in classroom settings are immediately apparent and consistent or emerge gradually over time in accord with extant models of ADHD, because none have analyzed for time effects or group by time interactions.

The primary purpose of the present study is to broaden our understanding of the attentional processes in children with ADHD while they function in a regular academic environment with multiple but naturally occurring (i.e., non-programmed) distractions. Direct observations are used to assess the attentive behavior of a large sample of children with ADHD relative to a cohort of control (non-ADHD) children, and to investigate the degree to which they support predictions stemming from the decrement, deficit, and hybrid models of attention. Children with ADHD are hypothesized to be significantly less attentive relative to normal controls, and both groups of children are expected to exhibit gradual declines in attention over time if laboratory findings of children’s vigilance mirror the same attentional processes required in classroom settings. Fundamental characteristics of children's classroom attention (e.g., attentional shifts) are scrutinized to illuminate potential differences in attentional processes between children with ADHD and normal controls, and to discern whether any differences that emerge are of diagnostic value.
METHODS

Sample

**Clinical Sample.** 134 children were screened for inclusion in the study following referrals from psychiatrists, pediatricians, and school personnel over a 5-year period. All children and their parents participated in a detailed, semi-structured clinical interview with the clinic’s supervising psychologist (MDR). The interview was adapted from the Schedule for Affective Disorders and Schizophrenia for School-age Children (Orvaschel, Puig-Antich, Chambers, Tabrizi, & Johnson, 1982) and reviewed symptoms associated with disorders usually evident in childhood and adolescence as outlined in DSM-III (American Psychiatric Association, 1980).

Children were required to meet the following inclusion criteria: (1) independent diagnosis by the referring physician and the supervising clinical psychologist using DSM-III criteria for Attention Deficit Disorder with Hyperactivity (ADDH); (2) maternal report of developmental history consistent with ADDH; (3) problems in at least 50% of the situations on Barkley’s (1990) Home Situations Questionnaire; (4) maternal ratings at least two standard deviations above the mean on the Werry-Weiss-Peters Activity Scale (Routh, Schroeder, & O’Tuama, 1974); (5) teacher ratings of at least two standard deviations above the mean on the Abbreviated Conners Teacher Rating Scale (ACTRS; Conners, 1973); (6) absence of Conduct Disorder; and (7) absence of gross neurological, sensory, or motor impairment as determined by pediatric examination.
Sixty-six boys and nine girls met criteria and participated in the study after their parents gave informed consent. Selected children were from 6 to 11 years of age (M = 8.51, SD = 1.25) and fell within the average range of intelligence (M = 102.28, SD = 10.90) based on the Peabody Picture Vocabulary Test (Dunn & Dunn, 1981). They were all Caucasian and from families of low to middle socioeconomic status (Hollingshead, 1975). Eight had experienced brief trials of stimulant therapy within the previous 4 years.

The children were all pervasively hyperactive based on clinical interview and rating scale data. A systematic review using current diagnostic nomenclature indicated that each of the 75 children would currently be classified as meeting criteria defining attention-deficit/hyperactivity disorder-combined type, as detailed in the DSM-IV (American Psychiatric Association, 1994), and this moniker will be used throughout the study. The clinical outcome of these children has been reported elsewhere (Rapport, Denney, DuPaul, & Gardner, 1994).

Many of these children showed symptoms of but did not meet formal criteria for mood and anxiety disturbances. Comorbidity for oppositional defiant disorder was not assessed because of the controversial nature of the disorder at the time the study was initiated. All selected children were attending regular elementary school classrooms although several received concurrent special education services. Learning disabilities were not specifically assessed.

Thirty-one of the 59 nonparticipating children met criteria and were enrolled in an abbreviated placebo-controlled medication trial and are not reported on here. Insufficient data were available for three children because of school conflicts and one child moved out of state before completing the study. The remaining 24 non-
participating children fell within the established score range on rating scales but showed histories inconsistent with ADHD (e.g., onset of symptoms after 7 years or duration less than 6 months).

**Control Sample.** The normal control sample consisted of 36 children (29 boys, 7 girls) between the ages of 6 and 11 years (M = 8.56, SD = 1.81) who were either same age and gender classmates of children with ADHD (n = 11) or attending regular education classrooms in several public elementary schools in a similar urban district (n = 25). This later subsample was randomly selected from classroom rosters, did not evidence symptoms of ADHD or other problem behaviors according to parent and teacher report, and had never been referred for an evaluation of learning or behavior problems. The normal control children were of average or above-average intelligence based on standardized test results provided by each child's school and from families of low to middle socioeconomic status. Teacher ratings on the ACTRS for all members of this group were within 1.5 standard deviations of the mean for the child's age.

There were no significant differences between the ADHD and normal comparison groups with respect to age, IQ, and socioeconomic status (all t-test contrasts >.05, ns). The presence of learning disability was not assessed in either group. All children were currently attending regular elementary school classrooms, although several of the ADHD children concurrently received special education services (usually in reading and processing skills).

**Procedures**

All children were observed in their regular classrooms for 20-minute intervals for 3 days during a 1-week time interval. No children with ADHD were
in the same classroom. Eleven control children were in the same classroom as a child with ADHD completing the same assignments (i.e., limited to one control child per ADHD classroom), whereas the remaining 25 controls were in different classrooms. Observations were completed during the morning hours at a time that was held constant across all observation sessions, and were arranged to coincide with the start of the child’s first in-seat academic assignment (i.e., children completed their assigned in-seat academic work, such as mathematics or language arts, throughout the observation period).

**Dependent Measures**

*Attention.* Direct observations of children’s on-task behavior were used to measure attention. On-task behavior emphasizes visual fixation to task relevant stimuli, a property common to most measures of attention, and exhibits superior precision, objectivity, and validity as a measure of classroom attention relative to teacher-rating scales (Abikoff et al., 1977; Schachar et al., 1986).

Trained undergraduate and graduate-level research assistants observed children for 60 consecutive intervals during each observation period throughout the study. Each interval was divided into 15-s of observation followed by 5-s for recording. A child’s behavior was categorized as either on- or off-task. Off-task behavior was defined as visual inattention to one’s materials for more than 2 consecutive seconds within each 15-s observation interval, unless the child was engaged in an alternative task-appropriate behavior (e.g., sharpening a pencil). Observers were situated in classrooms such that they (1) avoided direct eye contact with observed children, and (2) were distanced from them by approximately half the classroom size, while still allowing for clear determination
of task-related attention. Observers were blind to the diagnostic standing of all children.

Interobserver reliability checks of each child’s on-task behavior were obtained on 33% of the observation days and at least once during the week for all the participants in the study, excluding the eleven control children in the same classroom as a child with ADHD. The raters conducted reliability observations for only the children with ADHD in these cases based on past research showing that children with ADHD show more variability in their classroom behavior (DuPaul & Rapport, 1993). Obtained and chance estimates were computed for occurrence, non-occurrence, and overall agreement. Overall reliability was consistently greater than 85%, with a mean of 92.4% (range = 86.3 to 99.8) across children. A mean kappa value of .84 was obtained across all observations.
RESULTS

A three-tier data analytic strategy was used to examine the study’s primary hypotheses. Direct observations of children’s classroom attention – three, 20-s observations per minute over 20 contiguous minutes for 3 observation days – were transposed to twenty, 1-min time blocks (i.e., each 1-min time block was estimated based on 9 data points). A 2 (group: ADHD, normal control) X 20 (time blocks) Mixed Model ANOVA was used in the first tier, and complemented by post-hoc analyses and analysis of trend (Keppel, 1991) to examine hypotheses derived from the deficit, decrement, and hybrid models – specifically, whether significant differences in attention are immediately apparent or occur over time as predicted by the deficit/hybrid models and decrement model, respectively.

Logistic regression was computed for six variables (attentional shifts, mean number of on-task intervals, average sustained on-task intervals, average sustained off-task intervals, longest number of contiguous on-task intervals, longest number of contiguous off-task intervals) in the second tier analyses to discern how well each variable predicted group membership. Receiver operating characteristic (ROC) analyses provided sensitivity and specificity rates for determining diagnostic significance of the predictor variables. In the third tier, odds ratios were computed utilizing the logistic regression results to assess the relative likelihood of ADHD membership for each predictor variable.

Age was not significantly correlated with any of the 20, 1-min observation intervals for children with ADHD, and was correlated with only the final 1-min interval for normal controls ($r = 0.39$). No significant relationship emerged
between IQ and observed attention for either group. As a result, neither age nor IQ was included in the analyses.

**Tier I.** A 2 x 20 mixed model ANOVA yielded a significant effect for group, $F(1, 109) = 61.14, p < 0.0005$ (Cohen’s $d = 1.50$), a non-significant effect for time, $F(1, 19) = 1.04, ns$, and a significant group by time interaction effect, $F(1, 19) = 1.66, p < .05$. Group means for the 20, 1-min attention intervals are depicted in Figure 2.

A series of post-hoc analyses (t-tests) were conducted to address hypotheses derived from the three models. The between-group contrast for the initial time interval was not significant, $t = 1.93, ns$. This result indicates that children with ADHD and normal controls are not significantly different from one another initially in terms of attending to their assigned classroom work – a finding consistent with the decrement model’s central hypothesis. Significant between-group differences were found for all other 1-min time blocks across the 20-min observation period, including the final time block ($p < .0005$ for all contrasts). This finding also appears to support the decrement model (i.e., expected between-group differences for later time blocks). Inspection of Figure 2, however, illustrates that both groups’ attention by time curves are inconsistent with predictions stemming from the decrement model. The normal control group appears to exhibit an accelerating-decelerating pattern of behavior, whereas minute-to-minute variability appears to characterize the ADHD group. Analysis of trend was used to explicate these patterns.

The analysis of trend for children with ADHD was not significant for linear, quadratic, cubic, or quartic trends, yet revealed a significant 17th order trend, $p =$
.02 (see Table 1). This finding indicates that the ADHD group’s attention over time is best characterized as highly variable from one minute to the next. The shape of the normal control children’s attention over time, in contrast, was characterized by significant cubic and quartic trends (see Table 1), with the higher-order quartic trend accounting for the greatest amount of variance (see $R^2$ values in Table 1). This finding indicates that the shape of the normal control attention by time curve is characterized by three significant changes in slope and intercept, as no higher order trends were significant. Inspection of Figure 2 indicates that the three primary shifts in attention appear to occur at the 6th, 13th, and 19th intervals, consistent with an accelerating-decelerating-accelerating-decelerating pattern of attention over time.
A final set of t-tests was conducted to examine whether initial and final time intervals were significantly different within each group, consistent with predictions stemming from the decrement and hybrid models (i.e., both models predict lower final relative to initial time interval values and a more pronounced decrement effect in the ADHD relative to the control group). Results revealed that normal control children were significantly more attentive during the final compared to the initial time block ($t = 2.53, p = .016$), whereas this contrast was
not significant in the ADHD group ($t = .75, ns$). These results are inconsistent with predictions stemming from both the decrement and hybrid models.

Table 1 Analysis of Trend

<table>
<thead>
<tr>
<th>Group</th>
<th>Trend</th>
<th>$F$</th>
<th>$p$</th>
<th>$R^2_{\text{Trend}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADHD</td>
<td>Linear</td>
<td>0.019</td>
<td>0.89</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Quadratic</td>
<td>0.078</td>
<td>0.78</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cubic</td>
<td>2.346</td>
<td>0.13</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Quartic</td>
<td>0.068</td>
<td>0.80</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Order 17</td>
<td>5.376</td>
<td><strong>0.02</strong></td>
<td>0.068</td>
</tr>
<tr>
<td>Normal</td>
<td>Linear</td>
<td>2.744</td>
<td>0.11</td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>Quadratic</td>
<td>1.090</td>
<td>0.30</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cubic</td>
<td>5.056</td>
<td><strong>0.03</strong></td>
<td>0.126</td>
</tr>
<tr>
<td></td>
<td>Quartic</td>
<td>5.827</td>
<td><strong>0.02</strong></td>
<td>0.143</td>
</tr>
</tbody>
</table>

**Note:** Order 17 trend indicates 17 directional shifts in attention. $R^2 = \text{the percent of variance accounted for by the corresponding trend component.}$

**Tier II.** Total attention shifts, mean number of on-task intervals, mean number of sustained on- and off-task intervals, and longest number of contiguous on- and off-task intervals were examined using logistic regression to determine the optimal level of predicting group membership (see left-hand column of Table 3). All variables were derived from the on-task interval data and analyzed separately using logistic regression analysis to avoid inherent problems associated with multicolinearity. Total attention shifts represent all changes from one state to an alternate state (i.e., on-task to off-task or off-task to on-task). Mean number of on-task intervals represents each child’s average number of on-task intervals across the 20-min observation period. Sustained on- and off-task intervals represent the mean number of consecutive intervals the children remained on- or off-task during the 20-min observation period. Contiguous on- and off-task interval data represent the longest number of consecutive intervals in which children remained on- or off-task, respectively. All variables represent averages
over three days of observations. Means and standard deviations for the six criterion variables are shown in Table 2.

### Table 2 Means and Standard Deviations of Predictor Variables

<table>
<thead>
<tr>
<th>Variables</th>
<th>ADHD</th>
<th>Controls</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>X (SD)</td>
<td>X (SD)</td>
</tr>
<tr>
<td>Attention Shifts</td>
<td>15.32 (2.24)</td>
<td>10.99 (2.36)</td>
</tr>
<tr>
<td>Mean intervals on-task</td>
<td>34.02 (10.54)</td>
<td>48.27 (6.85)</td>
</tr>
<tr>
<td>Mean sustained on-task</td>
<td>4.65 (2.08)</td>
<td>10.07 (6.10)</td>
</tr>
<tr>
<td>Mean sustained off-task</td>
<td>4.14 (4.19)</td>
<td>2.24 (1.25)</td>
</tr>
<tr>
<td>Longest time on-task</td>
<td>11.52 (5.97)</td>
<td>21.61 (10.03)</td>
</tr>
<tr>
<td>Longest time off-task</td>
<td>8.82 (7.77)</td>
<td>3.93 (2.74)</td>
</tr>
</tbody>
</table>

**Note:** Attention Shifts represents all changes from one state to an alternate state. Mean number of on-task intervals represents each child’s average number of on-task intervals across the observation period. Mean sustained on- and off-task intervals represent the number of consecutive intervals the children remained on- or off-task averaged over the three days of observations. Longest time on- and off-task interval data represent the longest number of consecutive intervals in which children remained on-task or off-task, respectively. All values represent data averaged over the three days of observations.

Receiver operating characteristic (ROC) analyses illustrates the tradeoff between sensitivity and specificity by graphically depicting increases in correctly identified children with ADHD over decreases in correctly identified children without the diagnosis. Sensitivity increases on the ordinate as the number of ADHD children identified correctly increases (see Figure 3). One minus the specificity, the number of correctly identified normal control children, increases across the abscissa in a left to right fashion and denotes an increase of misclassification of normal control children into the ADHD group. Area under the curve (AUC) provides a measure of accuracy for the ROC curves, denoting how
well each variable separates the two groups. AUC values range from 0.5 (no discrimination by the variable) to 1.0 (perfect discrimination). Values ranging from 0.5 to 0.7 are considered low accuracy AUC, while 0.7 to 0.9 are recommended as useful ranges, and values greater than 0.9 indicate high accuracy measures (Swets, 1988). AUC values for the six variables are presented in Figure 3.

Inspection of the ROC plot for total attention shifts reveals the corresponding tradeoff between sensitivity and specificity – as sensitivity approaches 90%, specificity declines to 44%, whereas sensitivity decreases to 30% when specificity reaches 90% (see Figure 3-a). Logistic Regression was used to predict optimal group classification and indicates that 9.83 or more attention shifts is associated with a sensitivity rate of 92.0%, a specificity rate of 33.3%, and overall group classification or total predictive value (TPV) of 73.0% (see vertical dashed line in Figure 3-a).

Similar results were attained for other predictor variables. Sensitivity and specificity ranged from 33.3% to 63.9% and 85.3% to 90.7%, respectively. Overall prediction of group classification or TPV for the 6 variables ranged from 73.0% to 80.2%, with mean on-task being the best overall predictor of group membership (see TPV column in Table 3).
Figure 3 Receiver Operation Characteristics for Six Predictor Variables Dashed lines represent optimal level of prediction or total predictive value for variable. Area Under the Curve value (e.g., .74 in figure 3-a) represents the level of predictive accuracy for the ROC curve.
**Tier III.** Threshold values derived from the previous tier’s logistic regression results were used to determine the point that optimally separates the two groups for each of the six variables (see Table 3, left-hand column), and to calculate odds ratios for the six variables. The odds ratio indicates the relative likelihood (independent of base rate) of being from the ADHD rather than the normal control group if a particular threshold value is exceeded. An odds ratio ≥ 3 is recommended (Fleiss, 1981).

Table 3 reveals that 92.0% of the ADHD group exceeded the greater than 9.83 attention shift threshold (true positives), whereas 33.3% of normal control children did not exceed the threshold (i.e., true negatives). The corresponding odds ratio indicates that children who exhibit 10 or more attention shifts during a 20-min classroom observation are 5.75 times more likely to belong to the ADHD than the normal control group. Odds ratios for all six variables exceed recommended values, and are depicted in Table 3. The odds ratios for total attention shifts, mean sustained off-task intervals, and contiguous intervals of on- and off-task behavior were similar, ranging from 5.75 to 6.18. An odds ratio of 12.90 emerged for the mean on-task variable. This indicates that children who are paying attention in class less than 76.7% of the time during structured academic assignment periods are approximately 13 times more likely to be from the ADHD group. The odds ratio for the mean sustained on-task interval variable (i.e., continuous intervals paying attention) indicates that children who are paying attention for 2.5 min or less on average before shifting to an off-task state are 10.45 times more likely to be from the ADHD group of children.
<table>
<thead>
<tr>
<th>Variables (threshold values)</th>
<th>True Positives (ADHD children Correctly Identified)</th>
<th>False Negatives (ADHD children Incorrectly Identified)</th>
<th>True Negatives (Normal children Correctly Identified)</th>
<th>False Positives (Normal children Incorrectly Identified)</th>
<th>OR</th>
<th>TPV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total number of shifts (&gt; 9.83 shifts)</td>
<td>69 92.0</td>
<td>6 8.0</td>
<td>12 33.3</td>
<td>24 66.7</td>
<td>5.75</td>
<td>73.0</td>
</tr>
<tr>
<td>Mean time on-task (&lt; 46.08 intervals)</td>
<td>66 88.0</td>
<td>9 12.0</td>
<td>23 63.9</td>
<td>13 36.1</td>
<td>12.90</td>
<td>80.2</td>
</tr>
<tr>
<td>Mean Sustained on-task (&lt; 7.61 intervals)</td>
<td>67 89.3</td>
<td>8 10.7</td>
<td>20 55.6</td>
<td>16 46.4</td>
<td>10.45</td>
<td>78.4</td>
</tr>
<tr>
<td>Mean Sustained off-task (&gt; 1.76 intervals)</td>
<td>68 90.7</td>
<td>7 9.3</td>
<td>14 38.9</td>
<td>22 61.1</td>
<td>6.18</td>
<td>73.9</td>
</tr>
<tr>
<td>Longest time on-task (&lt; 20.00 intervals)</td>
<td>64 85.3</td>
<td>11 14.7</td>
<td>18 50.0</td>
<td>18 50.0</td>
<td>5.82</td>
<td>73.9</td>
</tr>
<tr>
<td>Longest time off-task (&gt; 3.17 intervals)</td>
<td>64 85.3</td>
<td>11 14.7</td>
<td>18 50.0</td>
<td>18 50.0</td>
<td>5.82</td>
<td>73.9</td>
</tr>
</tbody>
</table>

Note: ADHD n = 75; normal control n = 36. OR = Odds Ratio or the likelihood that children above the threshold value belong to the ADHD group (e.g., children with greater than 9.83 attention shifts are 5.75 times more likely to be in the ADHD group than the normal control group). TPV = Total Predictive Value, or the percentage of children correctly identified diagnostically by a predictor variable.
DISCUSSION

The present study invoked theoretical models of attention derived from laboratory investigations as a framework for understanding processes that contribute to classroom attention difficulties in children with ADHD. Decrement, deficit, and hybrid model predictions were empirically examined to discern whether ADHD children’s attention is best characterized by a primary deficit that is immediately apparent and relatively consistent over time, or by an inability to sustain attention over time relative to normal control peers. All children were expected to evince at least minimal attentional decrements over a 20-min observation interval based on extant developmental literature (e.g., Swanson, 1983).

Obtained results provide partial support for the deficit model. Children with ADHD were not significantly less attentive relative to same-age peers during the initial observation interval, but were less attentive during the ensuing 19 minutes of observation. Results indicate that the attentional focus of children with ADHD quickly dissipates, and is characterized by a pattern of behavior that vacillates between brief periods of attention interspersed with more lengthy periods of inattention throughout the academic assignment period. This pattern is highlighted by three significant findings relative to normal controls – a greater number of shifts from on- to off- and off- to on-task states (i.e., 15.3 vs. 10.9), a greater number of contiguous off-task intervals (i.e., 8.8 vs. 3.9), and fewer contiguous on-task intervals (i.e., 11.5 vs. 21.6) on average. The lack of sustained attentional focus in the children with ADHD results in a significantly lower overall rate of
attention relative to normal controls during the 20-min observation period as
evidenced by the wide and non-overlapping differences for group on-task means
following the initial observation interval (i.e., 56% vs. 77%).

Our findings also provide partial support for the decrement model and reveal
a previously undocumented phenomenon for understanding attentional processes
in children with ADHD. As a group, the normal control children exhibit an
accelerating-decelerating pattern of attention while engaged in academic
assignments. Inspection of the shift data, coupled with the contiguous on- and off-
task data, reveals that they focus on and are engaged in their academic
assignments for 3-min, 20-s on average, followed by 40-s of inattention before
refocusing on the task at hand. Children with ADHD, in contrast, fail to evince
this sustained focus-rest-refocus pattern of attention. Their task-related focus of
attention averages 1-min, 20-s, followed by a similar interval of inattentiveness
that averages 1-min, 40-s – a cycling rate twice that of normal control children.

Classic depictions of the decrement model in children based on the vigilance
literature indicate a gradual reduction in attention between 10 and 15 minutes
(Hooks et al., 1994). The robustness of this finding is well documented (Losier,
McGrath, & Klein, 1996), but fails to characterize the attention of children in the
present study regardless of group membership. Periods of focused attention are
considerably briefer, even for normal children, and decrements are observed after
only 1-min, 20-s in children with ADHD.

The discrepancy between laboratory and classroom studies of attention may
be due to several factors associated with conventional vigilance paradigms such
as the Continuous Performance Test (CPT). The prototypical CPT stimulus
display time is set at a value close to 200-msec, accompanied by an 800-msec inter-trial stimulus interval (for a review of CPT task parameters, see Denny, Rapport, & Chung, 2004, and Lossier et al., 1996). These parameters require rapid evaluation and response execution on a second-to-second basis, but place minimal demands on central executive processes and working- and long-term memory (Baddeley, 1986). The most frequently used CPT paradigm, for example, requires children to watch for an ‘A’ stimulus, and shift their focus of attention only when the letter ‘X’ appears immediately after seeing the ‘A’ stimulus. Alphabetic letters are held in working memory for evaluative purposes, whereas shifts of attention occur in proportion to the number of presented target (‘X’) stimuli before returning to monitor for ‘A’ stimuli. What begins as a controlled processing task quickly turns to an automatic processing task, wherein most children are quite capable of performing other operations while monitoring for target stimuli. In contrast, school-based academic assignments nearly always require the evaluation and encoding of complex and multipart stimuli, place heavier demands on working memory, long-term memory and interactive processes, and often necessitate written rather than automated (e.g., mouse clicks) responses to questions and problems. Normal children may intentionally engage in ephemeral respites while working on academic assignments as a means to manage their attention and minimize fatigue under these circumstances. Children with ADHD may not have developed this meta-cognitive strategy, or the underlying mechanisms required to control attention may be insufficiently developed to allocate attentional resources in this manner (Sergeant, 2000).
Investigations that elucidate the relationship between attention, academic performance, and scholastic achievement in children may provide some clues concerning suspect candidate cognitive processes. For example, a replication and expansion of the Fergusson and Horwood (1995) long-term scholastic achievement model of ADHD demonstrated that phonological working memory mediates the continuity between attention problems and long-term scholastic achievement even after controlling for individuals differences in age, SES, and intelligence (Rapport, Scanlan, & Denney, 1999). A majority of school-related academic work necessitates phonological processing and encoding. An underdeveloped or poorly functioning phonological working memory system translates into an inability to hold representational sets of information sufficiently long to contemplate questions and solve problems, and places extensive demands on available resources that quickly exhaust attentional capacity and focus. The expected outcome is a pattern of rapid cycling of attentional focus.

Inculcating working memory or other constructs (e.g., behavioral inhibition) as core deficits, however, must extend beyond merely demonstrating between-group differences on tasks and paradigms. Research also must elaborate and demonstrate the processes by which hypothesized anatomical underpinnings are reflected in cognitive processes such as working memory, and how these processes are related to primary behavior problems such as gross motor activity level and scholastic underachievement.

The value of the present study is to elucidate processes that may contribute to classroom attention difficulties in children with ADHD compared to their peers. Interpretation and generalization of these findings must be interpreted in light of
the study’s methodology. Direct observations were used to study attentional differences within the natural classroom environment where distractions are unplanned and frequent. Advantages associated with *in vivo* naturalistic studies nearly always represent a trade-off with experimental control. Observations were obtained during a small portion of the daily classroom activity (i.e., 20-min of seat work), and limited to the morning hours during a 1-week period during which time children completed math and language arts written assignments. These results may not generalize to other classroom arrangements, attention in school at other times during the day, observed attention while working on less demanding academic assignments, or for children with severe learning disability or co-morbid clinical disorders. The obtained effect size of 1.50 and mean between-group differences for observed attention of 21%, however, are highly consistent with previous studies of attention involving children with ADHD and normal controls in classroom settings (Kofler et al., 2004).

Methodological limitations notwithstanding, the results derived from the receiver operator characteristics, logistic regression, and odds ratio analyses have implications for the clinical evaluation and diagnosis of children with ADHD. They suggest that the ability to focus attention on academic assignments for greater than 2.5 contiguous minutes and pay attention for at least 15-min during a 20-min academic assignment period may be of diagnostic value. An inability to manage attention in this manner necessarily results in more frequent shifting of attention from one state to another, and these factors are likely to identify a high percentage of children who meet formal diagnostic criteria for ADHD similar to
those employed in this study. Whether this information contributes incrementally to standard diagnostic evaluation practices merits empirical scrutiny.

Managing attention places a considerable burden on controlled processing abilities and is essential for succeeding in most schoolwork. Children with ADHD experience significant difficulty focusing on academic tasks at school, while managing internally and externally generated distractions. Laboratory-based clinical investigations play a vital role in explicating potential underlying processes and motivational factors relevant to understanding these difficulties, but must be supplemented with direct observational studies to ensure that processes studied under highly controlled conditions mirror those required in the natural environment.
REFERENCES


