Journal of Attention Disorders

Variability of Attention Processes in ADHD: Observations From the Classroom

Mark D. Rapport, Michael J. Kofler, R. Matt Alderson, Thomas M. Timko, jr and George J. DuPaul

The online version of this article can be found at:

Published by:
SAGE

Additional services and information for *Journal of Attention Disorders* can be found at:

Email Alerts: http://jad.sagepub.com/cgi/alerts

Subscriptions: http://jad.sagepub.com/subscriptions

Reprints: http://www.sagepub.com/journalsReprints.nav

Permissions: http://www.sagepub.com/journalsPermissions.nav

Citations http://jad.sagepub.com/cgi/content/refs/12/6/563

Variability of Attention Processes in ADHD

Observations From the Classroom

Mark D. Rapport

Michael J. Kofler
University of Central Florida

R. Matt Alderson
Oklahoma State University

Thomas M. Timko, Jr.
University of Central Florida

George J. DuPaul
Lehigh University

Objective: Classroom- and laboratory-based efforts to study the attentional problems of children with ADHD are incongruent in elucidating attentional deficits; however, none have explored within- or between-minute variability in the classroom attentional processing in children with ADHD. **Method:** High and low attention groups of ADHD children defined via cluster analysis, and 36 typically developing children, were observed while completing academic assignments in their general education classrooms. **Results:** All children oscillated between attentive and inattentive states; however, children in both ADHD groups switched states more frequently and remained attentive for shorter durations relative to typically developing children. **Conclusion:** Overall differences in attention and optimal ability to maintain attention among the groups are consistent with laboratory studies of increased ADHD-related interindividual and intergroup variability but inconsistent with laboratory results of increased intra-individual variability and attention decrements over time. (*J. of Att. Dis. 2009; 12(6) 563-573*)

Keywords: ADHD; vigilance; attention; variability; on task

ADHD is a complex, chronic neurodevelopmental disorder with behavioral and cognitive consequences that affect multiple areas of functioning in an estimated 3% to 5% of school-age children. Clinical consensus and theory purport that developmentally inappropriate and functionally impairing inattentiveness represents one of the core features of ADHD (American Psychiatric Association [APA], 2000) following the seminal work of Douglas (1972) and colleagues. Competing models, however, consider attentional problems a secondary (Barkley, 2006) or associated feature (Castellanos & Tannock, 2002; Rapport, Chung, Shore, & Issacs, 2001; Sonuga-Barke, 2002) of the disorder. The current study is the first to empirically test contradictory laboratory-based predictions of sustained attention decrements and increased behavioral variability in

children with ADHD relative to typically developing (TD) children in natural classroom settings. Although 23 previous studies have examined group-level on-task differences between ADHD and TD children (Kofler, Rapport, & Alderson, 2008), the current study is the first to examine minute-to-minute and within-minute attentional shifts in their directly observed classroom attentive behavior. The need for the current study is predicated on inconsistencies between the findings of classroom and laboratory studies of ADHD-related attention deficits, as reviewed subsequently.

Authors' Note: Please address all correspondence to Mark D. Rapport, Department of Psychology, University of Central Florida, 4000 Central Florida Blvd., Orlando, FL 32816; e-mail: mrapport@pegasus.cc.ucf.edu.

Efforts to study the attentional problems of children with ADHD have traditionally followed a two-pronged approach—examining vigilance/sustained attention performance differences under highly controlled laboratory conditions and using direct observations of attention in field settings such as the classroom. Controlled laboratory investigations are inconsistent in documenting attentional disturbance in children with ADHD. Significant differences are frequently, albeit not always, reported between ADHD and TD children while identifying infrequently occurring stimuli over extended periods of time as measured by continuous performance tests (CPTs; for a review, see Denney, Rapport, & Chung, 2005). Surprisingly few studies explore Group × Time interaction effects, and of those that do, several (Corkum, Schachar, & Siegel, 1996; Hooks, Milich, & Lorch, 1994; Seidel & Joschko, 1991; van der Meere, Shalev, Börger, & Gross-Tsur, 1995) but not all (Alberts & van der Meere, 1992; Barkley, Anastopoulos, Guevermont, & Fletcher, 1991; Harper & Ottinger, 1992) report significantly greater performance decrements over time in children with ADHD relative to TD children.

In contrast to the controlled laboratory investigations, no study to date has examined potential Group × Time interactions in attention in classroom settings (Kofler et al., 2008). Efforts to study the attentional problems of children with ADHD in field settings such as the classroom traditionally rely on direct observations, which are the most frequently used assessment method by school psychologists applying *Diagnostic and Statistical Manual of Mental Disorders* (4th ed.; APA, 1994) criteria (Wilson & Reschly, 1996). The value of direct observations is also recognized by the International Statistical Classification of Diseases and Related Health Problems, which requires a direct observation of on-task behavior during academic or other tasks to confirm a diagnosis of hyperkinesis/ADHD because of its recognition of the insufficient predictive validity of available rating scales (World Health Organization, 1993). Investigating the processes underlying classroom attention is particularly relevant given that classroom inattention is often the catalyst for clinical referrals (APA, 2000; Pelham, Fabiano, & Massetti, 2005), correlates highly with multiple pejorative outcomes, and portends immediate-, near-, and long-term functioning both within and external to the educational setting. Inattentive children complete less schoolwork correctly (Rapport, Denney, DuPaul, & Gardner, 1994) and are more likely to receive lower grades and standardized test scores (Zentall, 1993). More than half of all children with ADHD fail at least one grade by adolescence (Barkley, DuPaul, & McMurray, 1990), and 23% to 32% of children with ADHD fail to finish high school (Barkley, Fischer,

Smallish, & Fletcher, 2006; Mannuzza, Klein, Bessler, Malloy, & LaPadula, 1993). Classroom attentional problems identified in young children predict scholastic underachievement during adolescence (Rapport, Scanlan, & Denney, 1999) and early adulthood (Fergusson & Horwood, 1995), and their negative impact continues into adulthood—longitudinal studies reveal that they are less likely to attend college and more likely to have conduct problems, unstable marriages, and lower mean socioeconomic status scores compared to peers of similar intelligence (Barkley et al., 2006; Mannuzza et al., 1993).

Extant research examining classroom attentional difficulties in children with ADHD unequivocally reveals that they pay less attention during instruction and independent work periods than their peers and experience significant difficulty initiating and maintaining attention in academic settings (e.g., Abikoff et al., 2002; Barkley et al., 1990). Differences in rates of directly observed visual attentive behavior between children with ADHD and their unaffected peers vary between 4% and 27%, with a mean of 13%, after accounting for methodological, situational, and diagnostic differences across studies based on a recent meta-analytic review of 23 classroom observation studies (Kofler et al., 2008). These deficiencies are apparent regardless of coding schema, time interval, or participant demographics; are particularly apparent on tasks that place greater demands on working memory (Douglas, 1988; Rapport, Chung, Shore, Denney, & Issacs, 2000); and may be attenuated under conditions that involve novel task parameters (Power, 1992; Zentall & Meyer, 1987) and frequent reinforcement (Pelham, Milich, & Walker, 1986).

The consistent findings of classroom observation studies are at odds with the inconsistent laboratory CPT findings, necessitating empirical examination of attention processes in classroom settings. This discrepancy is accentuated by studies comparing CPT findings with direct observations of attention in the classroom. For example, studies examining the relationship between CPT errors and classroom attention frequently report nonsignificant (Conners, 1997; McGee, Clark, & Symons, 2000) or weak correlations (Nigg, Hinshaw, & Halperin, 1996), whereas stronger correlations are reported between direct observations of children's visual attention during the CPT and direct observations of their classroom visual attention (Börger et al., 1999; Weis & Totten, 2004). These findings may reflect the blurring of construct distinctiveness between laboratory definitions of vigilance and classroom measures of attention and the selection of discrete time intervals for study. For example, extant studies frequently equate laboratory-based vigilance and sustained attention as the ability to maintain a stable level of accurate responding, with deficits implied by a linear drop in performance

over time. This view is inconsistent with the often-replicated finding that reaction time variability may distinguish children with ADHD from controls better than traditional CPT measures (Banaschewski et al., 2003; Börger et al., 1999; Swaab-Barneveld et al., 2000). Therefore, it is equally plausible that children with attention deficits evince more of a nonlinear "in and out" pattern of attending. This view is tested directly in the current study by analyzing directly observed minute-to-minute and within-interval attentional shifts in children with ADHD and their unaffected peers.

Several laboratory studies have examined inter- and intra-individual variability in ADHD relative to TD children, leading to the consideration of ADHD-related variability as a candidate endophenotype of ADHD (Aase & Sagvolden, 2006; Castellanos et al., 2005; Kuntsi, Oosterlaan, & Stevenson, 2001; Leth-Steensen, Elbaz, & Douglas, 2000). Castellanos et al. (2005), for example, examined ADHD-related variability in reaction time on laboratory tasks using advanced signal processing techniques (e.g., Fast Fourier transformations and wavelet analyses) and found that children with ADHD exhibited greater overall variability as well as increased intra-individual variability relative to TD children. None of the classroom observation studies to date, however, have explored Group × Time interactions or minute-by-minute changes that may reflect variability in underlying attentional processes between children with ADHD and TD children (Kofler et al., 2008). This latter approach is used in the current study and has two potential advantages over traditional methods: It enables the investigation of momentary attentional variability or pattern differences in children with ADHD and provides preliminary data concerning the attentional characteristics and variability of TD, same-age peers in classroom settings. The approach also provides incremental benefit beyond the signal processing analyses used by others because it retains readily interpretable metrics (e.g., minutes and number of attention shifts, compared to Hertz).

The present study is the first to investigate variability in observed classroom attention. It scrutinizes minute-by-minute and within-minute interval changes in ADHD children's visual attention while they complete assigned academic seat work in general education classrooms with multiple but spontaneously occurring (i.e., non-programmed) distractions. Previous studies have used identical or similar coding schemes but have limited their analyses to group means (Kofler et al., 2008). Observational data collected in general education classrooms provide a unique opportunity to study children's attentional processes as they naturally occur, while maximizing ecological validity by taking into account situational and temporal influences (Kazdin, 1998). The inherent tradeoff between ecological validity and experimental control is unavoidable; however, these costs are often offset by the heuristic value gained through field studies. The study also includes same-aged TD children. Their inclusion enables between-group comparisons of attentional differences both within and across observation intervals and serves the unique function of providing an initial glimpse of TD children's attention in the classroom.

Method

Participants

Clinical participants. Sixty-six boys and nine girls referred by community psychiatrists, pediatricians, and school personnel met the following inclusion criteria and participated in the study: (a) diagnosis of ADHD based on parent clinical interview using the Schedule for Affective Disorders and Schizophrenia for School-Age Children (Ambrosini, 2000). (b) problems in at least 50% of the situations on Barkley's (2006) Home Situations Questionnaire, (c) a maternal rating of at least two standard deviations above the mean on the Werry-Weiss-Peters Activity Scale (Routh, Schroeder, & O'Tuama, 1974), (d) a teacher rating of at least two standard deviations above the mean on the Abbreviated Conners Teacher Rating Scale (ACTRS; Conners, Sitarenios, Parker, & Epstein, 1998), (e) absence of Conduct Disorder, and (f) absence of gross neurological, sensory, or motor impairment as determined by pediatric examination. Parents provided informed consent. 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, 1997). They were all Caucasian and from families of low to middle socioeconomic status (Hollingshead, 1975). Children were referred and evaluated for inclusion in a psychostimulant medication trial. Eight had experienced brief trials of stimulant therapy within the previous 4 years, but none were prescribed psychostimulants at the time of the study. Several children showed symptoms of, but did not meet formal criteria for, mood, anxiety, Oppositional Defiant, and Conduct Disorders. Increasing the heterogeneity of the ADHD group by including children comorbid for other disorders would impair interpretation of research findings as argued elsewhere (e.g., Vaessen & van der Meere, 1990). All selected children met criteria for ADHD–Combined Type and were attending general

education elementary school classrooms, although several received concurrent special education services.

TD children. The TD group consisted of 36 children (29 boys, 7 girls) between the ages of 6 and 11 ($M = 8.56$, $SD = 1.81$) who were either same age and gender classmates of children with ADHD ($n = 11$) or attending general education classrooms in several public elementary schools in a similar urban district ($n = 25$). This latter 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. There were no significant differences in observed rates of attention between the 11 classmate and 25 nonclassmate TD children ($p > .05$, *ns*). 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. The TD 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. There were no significant differences between the ADHD and normal comparison groups with respect to age, IQ, and socioeconomic status (all *t*-test contrasts $p > .05$, *ns*).

Procedures

All children were observed in their general education classrooms for 20 min on each of 3 days during a 1 week time span. No two children with ADHD were in the same classroom. Eleven TD children were in the same classroom as a child with ADHD completing the same assignments (limited to one control child per classroom of a participant with ADHD), whereas the remaining 25 TD children were in different classrooms. Observations were completed during the morning at a time that was (a) held constant across all observation sessions and (b) arranged to coincide with the start of children's initial 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 Measure

Visual attention. Direct observations of children's on-task behavior were used to measure visual 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 and parent rating scales (Abikoff et al., 2002; Harris & Lahey, 1982). Definitions of attention in the literature refer to preferential selection and processing of

sensory information—inattention is inferred from frequent shifts in activity and behaviors that are not task related (Bear, Connors, & Paradiso, 2001). Consistent with extant direct observation studies, the current study operationalizes attention as on-task behavior—visual attention to required stimuli.

A trained undergraduate- or graduate-level research assistant observed each child for 60 consecutive intervals during each observation day 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 using a partial interval schedule. The recent meta-analytic review by Kofler et al. (2008) found no difference between studies defining off task based on partial or whole intervals. Off-task behavior was defined as visual inattention to one's materials for more than 2 consecutive seconds within each 15-second observation interval, unless the child was engaged in an alternative task-appropriate behavior (e.g., sharpening a pencil). An observer was situated in each classroom such that they (a) avoided direct eye-to-eye contact with observed children, (b) were distanced from them by approximately half the classroom size, and (c) maintained a clear view of the child to allow determination of task-related attention. Observers were blind to children's diagnostic standing.

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 11 control children in the same classroom as children with ADHD. Reliability observations were conducted exclusively for children with ADHD in these cases because they exhibit higher variability in classroom attention. Obtained and chance estimates were computed for occurrence, nonoccurrence, 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.

A three-tier data analytic strategy was used to examine characteristics and variability in classroom visual attention. Dependent variables derived from the raw on-/off-task data for Tiers I and II are as follows: The direct observations of children's classroom attention—three observations of on-/off-task behavior per minute (20 s each) over 20 consecutive min on each of three observation days—were transposed to 20, one minute time blocks. Each 1-min time block was estimated based on nine data points, three from each observation day, and represents the percentage of each minute for which each child was on task across the three days. Each observation period coincided temporally with the beginning of that day's academic tasks; therefore, observation data points

were averaged across days to minimize history effects. The dependent variables for Tier III are described below.

Cluster analysis was used in the initial tier predicated on past findings that severity of attention and other executive functioning deficits often differentiate subgroups of children with ADHD with distinct neurocognitive profiles. Heritability studies employing latent class analysis reveal distinct subgroups of ADHD children with few, mild, and severe inattention that are genetically independent (Rasmussen et al., 2004; Todd et al., 2001). Children in the severe and mild inattention subgroups demonstrate specific impairments on standardized measures of reading, writing, mathematics, and verbal intelligence; frequency of failing grades; and use of special education services (Todd et al., 2002). Subgroups of mild and severe inattention have also been found to differ on age (Marsh & Williams, 2004) and severity of academic performance deficits—that is, 6.9% of the mild subgroup receive primarily C, D, and F grades, compared to 19.4% of the severe subgroup (Todd et al., 2002). In the current study, findings of distinct ADHD but not TD clusters would indicate increased ADHD-related intragroup variability.

Within- and between-minute differences in attention were explicated in the second and final tiers. Tier II used the derived data described earlier and examined Group (ADHD, TD) × Time (Minutes 1 to 20) interactions and variability over time to investigate intergroup and intra-individual variability, respectively. A significant Group × Time interaction would indicate increased intergroup variability, whereas significantly higher *SDs* across minutes in both ADHD groups relative to TD children would suggest increased intra-individual ADHD-related variability. An attention decrement, on the other hand, would be demonstrated by a temporal pattern in which the visual attention rates of children with ADHD decrease over time disproportionately to the rates of TD children.

Tier III analyzed the characteristics and patterns of classroom visual attention. Six variables were derived from the raw on-/off-task data: (a) overall mean time on task, mean duration of time (b) on and (c) off task, maximum duration (d) on and (e) off task, and (f) total shifts. Mean overall time on task was calculated based on each child's average number of on-task intervals across the three 20-min observation days. Mean duration on and off task were calculated based on the average number of consecutive minutes children remained on and off task before switching to the alternate behavioral state (i.e., "On average, how long did they remain on task before going off task?"). Maximum time on and off task, in contrast, represent the longest period of time each child ever remained on or off task, respectively, once entering

that state. Total attention shifts represent all changes from one state to the alternate state (i.e., on task to off task and off task to on task). All variables represent averages over 3 days of observations.

Results

Tier I: Cluster Analysis and Group Assignment

Attentional data for the ADHD and TD groups were submitted to separate two-step cluster analyses (Hair, Anderson, Tatham, & Black, 1998) to determine whether children with ADHD and TD children were best represented as single or multiple subgroups based on observations of their attention over time. The ADHD and TD groups were analyzed separately for conceptual reasons (i.e., inclusion criteria separated them based on attention ratings and other factors). The cluster analytic solution revealed that TD children were best represented as a single group, whereas a two-group solution optimally characterized children with ADHD based on Schwarz Bayesian Information Criterion (BIC). The BIC is a model-fitting index, wherein the lowest BIC value indicates the preferred cluster solution (Hair et al., 1998). Cluster solution values are presented in Table 1. The Tiers II and III analyses are therefore based on three groups: one cluster of TD and two clusters of children with ADHD. The two ADHD groups were designated ADHD-High Attention (ADHD-H; $n = 47$) and ADHD-Low Attention (ADHD-L; $n = 28$) based on their mean on-task rates. The ADHD-H and ADHD-L groups did not differ on age, gender, IQ, Werry-Weiss-Peters Activity Scale, ACTRS, Home Situations Questionnaire scores, or presence of subclinical symptoms of other disorders (all $p > .10$).

Tier II: Attention by Time Analysis

Intergroup variability over time. A 3 (Group: ADHD-L, ADHD-H, and TD) × 20 (Time Blocks) mixed model ANOVA was conducted to examine main and interaction effects of the three groups over time. Obtained results yielded a significant main effect for group, $F(1, 108) = 135.81$, $p < .001$, a nonsignificant main effect for time, $F(1, 19) = 0.82$, *ns*, and a significant Group × Time interaction effect, $F(1, 38) = 1.62$, $p = .01$. Group means and 95% confidence intervals for the 20 minute observational period are depicted in Figure 1.

Post hoc analyses with Bonferroni corrections for multiple comparisons indicated that children in the ADHD-H and TD groups exhibit relatively similar on-task rates at the onset of the 20-min seatwork assignment

Figure 1
Mean Percentage of On-Task Behavior for 20 Consecutive One Minute Observation Intervals Averaged Across Three Days for Three Groups of Children: TD, ADHD-High, and ADHD-Low
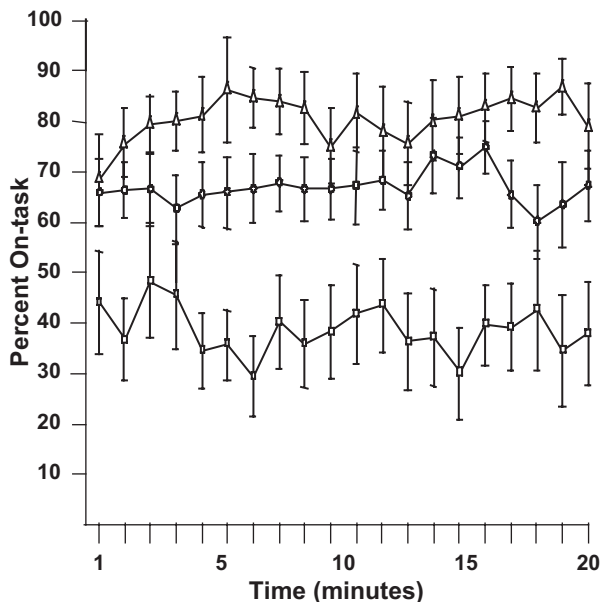
Note: TD = Percent on-task for three groups: typically developing children (top); ADHD-High Attention (middle); ADHD-Low Attention (bottom). Standard error bars represent the 95% confidence interval.

period (Minutes 1 and 2: $p \geq .13$). The TD group, in contrast, shows clear separation from the ADHD-H group between the 3rd and 11th minutes of observation (all $p < .05$). The ADHD-H and TD groups did not differ during Minutes 12 to 16 (all $p \geq .13$), differed during Minutes 17 to 19 (all $p < .001$), and did not differ during the final minute ($p = .12$). The significant Group × Time interaction is therefore due to the differential visual attention pattern of TD children. They were the only group with a significant main effect for time ($p = .02$),

which trend analysis revealed was characterized by a significant quartic (fourth order) trend ($p = .03$). In other words, the significant differences found between the ADHD-H and TD groups were not due to decrements in ADHD-H on-task rates over time but instead to significant increases in TD visual attention rates over time. The mean on-task rate for children in the ADHD-L ($n = 28$) group was significantly lower than both ADHD-H and TD children across all 20 min (all $p < .002$).

Intra-individual variability over time. Individual variability in visual attention rates across time was assessed by estimating each participant's variability over time and comparing these estimates across groups. Standard deviations were calculated for each participant across the 20 data points and compared using a one-way ANOVA. Results indicated a main effect for group, $F(2, 108) = 3.34$, $p = .04$. Bonferroni-corrected post hocs revealed that the ADHD-L group was significantly more variable over time compared to TD children ($p = .05$). Children with ADHD-H did not differ from children with ADHD-L or TD children (both $p \geq .12$).

Tier III: Patterns and Processes of Visual Attention

To examine characteristics and patterns of children's classroom attention, a series of six one-way ANOVAs were conducted on mean overall time on task, mean duration on and off task, maximum duration on and off task, and total shifts. ANOVA results revealed a significant group effect for all six variables: mean overall time on task, $F(2, 108) = 122.62$, $p < .001$, mean duration on task, $F(2, 108) = 28.27$, $p < .001$, mean duration off task, $F(2, 108) = 17.27$, $p < .001$, maximum duration on task, $F(2, 108) = 36.93$, $p < .001$, maximum duration off task, $F(2, 108) = 38.26$, $p < .001$, and total shifts, $F(2, 108) = 11.01$, $p < .001$. Post hoc Bonferroni analyses revealed significant differences between all three groups for all variables at the $p < .001$ level with three exceptions. The ADHD-H and TD groups were not significantly different in their mean duration off task and maximum duration off task, and the two ADHD groups did not differ significantly in the frequency of their attentional shifts (all three ps > .05). These findings are depicted in Figures 2 and 3.

Discussion

This investigation is the first to examine between- and within-minute attentional processes in children with ADHD relative to same-age, TD children while they

Figure 2
Mean Duration On and Off Task: Average Duration of Time Children Remained
On and Off Task Before Switching to the Alternate State
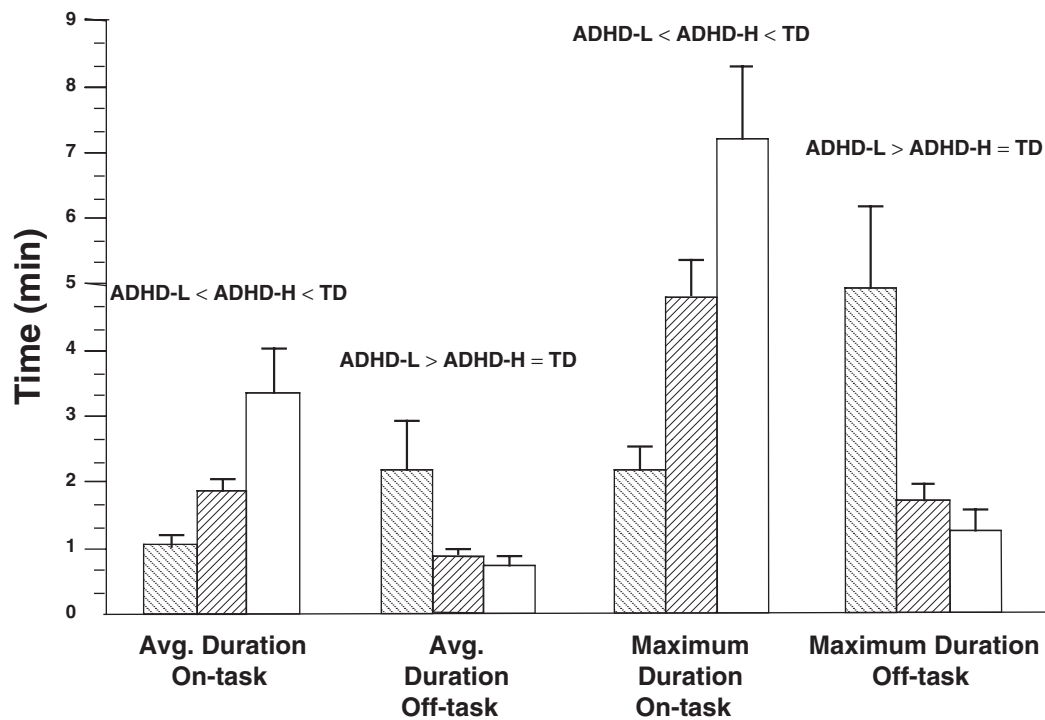
Note: ADHD-L = ADHD–Low Attention; ADHD-H = ADHD–High Attention; TD = typically developing. Maximum duration on and off ask: Longest duration of consecutive minutes children ever remained on or off task after switching to that state. Error bars = 95% confidence interval. Between-group significant differences = $p < .001$ level.

complete academic assignments in general education classrooms. Obtained between-group differences in mean rates of visual attention are highly consistent with previous classroom investigations of attention involving children with ADHD and TD children (Kofler et al., 2008). ADHD-H and ADHD-L subgroups were defined via cluster analysis and found to be off task approximately 13% and 40% more often than TD children, respectively. The attentional characteristics and variability that contributed to these differences were of primary interest.

The present study's findings are consistent with past findings of higher performance variability in children with ADHD (Banaschewski et al., 2003; Barkley, 2006; Castellanos et al., 2005). All children oscillated between visually attentive and inattentive states. Children in both ADHD groups, however, oscillated between on and off task more frequently and remained visually attentive for shorter durations relative to TD children. The distinct clusters of children with ADHD, despite diagnostic and demographic homogeneity, reflect increased interindividual variability in ADHD. Children in the ADHD-H

group remained visually attentive and inattentive for longer and shorter average and maximum durations than ADHD-L children, respectively. Examination of intra-individual variability in visual attention rates over time revealed that only children in the ADHD-L group were more variable over time than TD children. The present study, therefore, is consistent with previous laboratory findings of increased intergroup and interindividual variability in children with ADHD relative to TD children (e.g., Castellanos et al., 2005). Increased intra-individual variability, on the other hand, appears limited to a subgroup of children with ADHD characterized by more severe impairments in their classroom visual attention.

Both the overall differences in attention (80%, 67.5%, and 39.5%) and wide differences in optimal ability to maintain attention (7 minute, 5 minute, and 2 minute) among the TD, ADHD-H, and ADHD-L groups, respectively, are consistent with predictions derived from attention deficit (Douglas, 1999), attentional resource (Sergeant, Oosterlaan, & van der Meere, 1999), and working memory models of ADHD (Rapport, Alderson et al., 2008; Rapport

Figure 3
Overall Mean Time On Task and Frequency of Attention Shifts
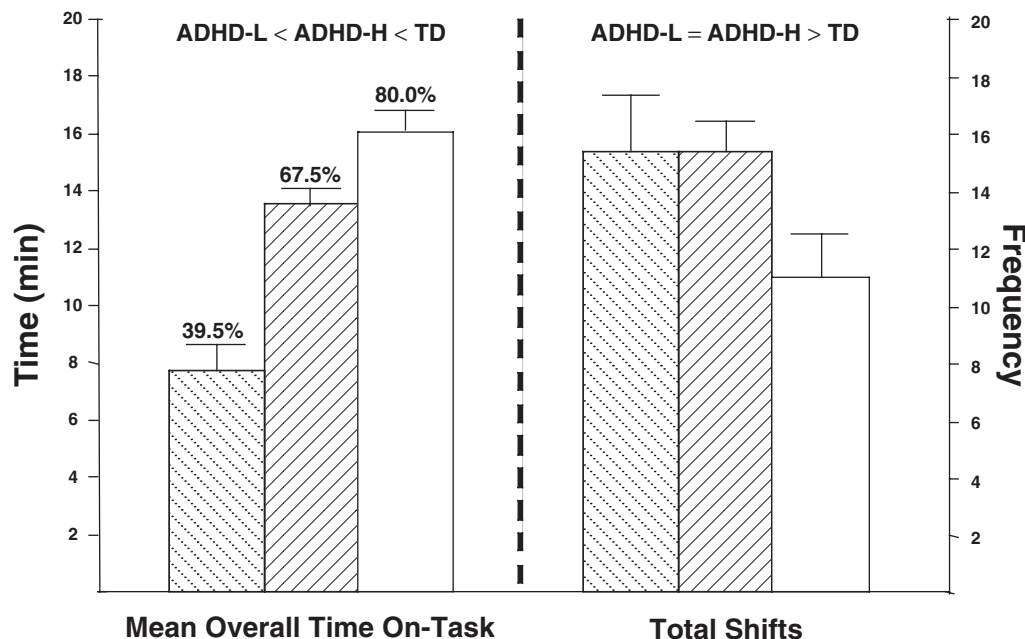
Note: ADHD-L = ADHD–Low Attention; ADHD-H = ADHD–High Attention; TD = typically developing. Total shifts = mean shifts from one state to the alternate state (i.e., on task to off task and off task to on task). Left ordinate = time in minutes; right ordinate = total shift frequency. Error bars = 95% confidence interval. Between-group significant differences = $p < .001$ level.

et al., 2001; Rapport, Kofler, Alderson, & Raiker, 2008) but inconsistent with decrement models that predict a linear decline in attention over time (Corkum et al., 1996; Hooks et al., 1994). Empirical investigations are needed to determine whether these deficits reflect discrete categorical differences or a population continuum as suggested elsewhere (cf., Gjone, Stevenson, & Sundet, 1996).

Significant differences were observed in frequency of attentional shifts between children in both ADHD groups compared to their unaffected peers. This finding is also inconsistent with CPT-based decrement model predictions, which forecast progressively longer periods of inattentive behavior over time. Several factors may account for these differences. Traditional CPTs place minimal demands on working memory and most rely on automatic processing (Denney et al., 2005). The experimental manipulation typically invokes strong demand characteristics, wherein children sit alone at a station in a quiet room while letters or numbers are rapidly shown on a computer. Classroom academic tasks, in contrast, typically involve controlled processing and place greater demand on cognitive resources, including the ability to store and manipulate information in working memory. The processes studied by the CPT do not appear to be the same that operate in classroom settings or at best represent a very limited part of the processes.

Of perhaps greater interest is what occurs when children stop attending to their academic assignments. The ADHD-H and TD groups remain off task for less than 1 min before returning to their work, whereas the ADHD-L children remain inattentive for approximately twice as long on average. Several environmental factors may have contributed to these findings (Rapport et al., 2000). Changes in both classroom structure and task demands (Barkley et al., 1990; Jacob, O'Leary, & Rosenblad, 1978; Power, 1992; Whalen et al., 1978; Zentall & Meyer, 1987) are known to differentially affect the classroom attention of children with ADHD and TD children. Working memory has also been implicated in classroom attention because of its relationship with multiple cognitive and self-regulatory functions as discussed elsewhere (Gathercole & Alloway, 2008).

The value of the present study was to elucidate characteristics and variability 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 tradeoff with experimental control. Observations of children completing math and language arts written assignments were obtained during a short duration at the onset of daily academic activity (i.e., 20 min of seat work on each of 3 days) and limited to the morning hours during a 1-week period. These results may not generalize to other classroom arrangements, attention in school at other times of the day, observed attention while working on less demanding academic assignments, or children with severe learning disability or comorbid clinical disorders. As an initial study, we felt that the inclusion of a more heterogeneous group may have hindered interpretation of research findings, as argued elsewhere (e.g., Vaessen & van der Meere, 1990). The obtained rates of attention for both the TD children and children with ADHD, however, were highly consistent with those reported in a recent meta-analytic review (Kofler et al., 2008) and strengthen the potential generalization of the findings. Attention, at its most general level, can be viewed as a correlation between environmental stimuli and behavior (Barkley, 2006). The processes involved in the complex strategic systems required for the self-regulation, planning, and implementation of goal-directed behavior—which can adapt flexibly to environmental changes such as those required in classroom settings—are daunting but deserving of focused empirical investigation.

References

Aase, H., & Sagvolden, T. (2006). Infrequent, but not frequent, reinforcers produce more variable responding and deficient sustained attention in young children with attention-deficit/hyperactivity disorder (ADHD). *Journal of Child Psychology and Psychiatry*, *47*, 457-471.

Abikoff, H. B., Jensen, P. S., Arnold, L. L., Hoza, B., Hechtmen, L., Pollack, S., et al. (2002). Observed classroom behavior of children with ADHD: Relationship to gender and comorbidity. *Journal of Abnormal Child Psychology*, *30*, 349-359.

Alberts, E., & van der Meere, J. J. (1992). Observations of hyperactive behaviour during vigilance. *Journal of Child Psychology & Psychiatry*, *33*, 1355-1364.

Ambrosini, P. J. (2000). Historical development and present status of the Schedule for Affective Disorders and Schizophrenia for School-Age Children (K-SADS). *Journal of the American Academy of Child & Adolescent Psychiatry*, *39*, 49-58.

American Psychiatric Association. (1994). *Diagnostic and statistical manual of mental disorders* (4th ed.). Washington, DC: Author.

American Psychiatric Association. (2000). *Diagnostic and statistical manual of mental disorders* (4th ed., text revision). Washington, DC: Author.

Banaschewski, T., Brandeis, D., Heinrich, H., Albrecht, B., Brunner, E., & Rothenberger, A. (2003). Association of ADHD and conduct disorder—Brain electrical evidence for the existence of a distinct subtype. *Journal of Child Psychology and Psychiatry*, *3*, 356-376.

Barkley, R. A. (2006). *Attention-Deficit Hyperactivity Disorder: A handbook for diagnosis and treatment* (3rd ed.). New York: Guilford.

Barkley, R. A., Anastopoulos, A. D., Guevermont, D. C., & Fletcher, K. E. (1991). Adolescents with ADHD: Patterns of behavioral adjustment, academic functioning, and treatment utilization. *Journal of the American Academy of Child & Adolescent Psychiatry*, *30*, 752-761.

Barkley, R. A., DuPaul, G. J., & McMurray, M. B. (1990). Comprehensive evaluation of attention deficit disorder with and without hyperactivity as defined by research criteria. *Journal of Consulting & Clinical Psychology*, *58*, 775-789.

Barkley, R. A., Fischer, M., Smallish, L., & Fletcher, K. (2006). Young adult outcome of hyperactive children: Adaptive functioning in major life activities. *Journal of the American Academy of Child & Adolescent Psychiatry*, *45*, 192-202.

Bear, M. F., Connors, B. W., & Paradiso, M. A. (2001). *Neuroscience: Exploring the brain* (2nd ed.). Philadelphia: Lippincott Williams & Wilkins.

Börger, N., van der Meere, J., Ronner, A., Alberts, E., Geuze, R., & Bogte, H. (1999). Heart rate variability and sustained attention in ADHD children. *Journal of Abnormal Child Psychology*, *27*, 25-33.

Castellanos, F. X., Sonuga-Barke, E. J., Scheres, A., Di Martino, A., Hyde, C., & Walters, J. R. (2005). Varieties of attention-deficit/hyperactivity disorder-related intra-individual variability. *Biological Psychiatry*, *57*, 1416-1423.

Castellanos, F. X., & Tannock, R. (2002). Neuroscience of attention-deficit/hyperactivity disorder: The search for endophenotypes. *Nature Reviews Neuroscience*, *3*, 617-628.

Conners, C. K. (1997). *Conners' Rating Scales-Revised technical manual*. Toronto, Ontario, Canada: Multi-Health Systems.

Conners, C. K., Sitarenios, G., Parker, J. D., & Epstein, J. N. (1998). Revision and restandardization of the Conners teacher rating scale (STRS-R). *Journal of Abnormal Child Psychology*, *26*, 279-291.

Corkum, P. V., Schachar, R. J., & Siegel, L. S. (1996). Performance on the continuous performance task and the impact of reward. *Journal of Attention Disorders*, *1*, 163-172.

Denney, C. B., Rapport, M. D., & Chung, K. M. (2005). Interactions of task and subject variables among continuous performance tests. *Journal of Child Psychology and Psychiatry*, *46*, 420-435.

Douglas, V. I. (1972). Stop, look and listen: The problem of sustained attention and impulse control in hyperactive and normal children. *Canadian Journal of Behavioural Science*, *4*, 259-282.

Douglas, V. I. (1988). Cognitive deficits in children with Attention Deficit Disorder with Hyperactivity. In L. M. Bloomingdale & J. Sergeant (Eds.), *Attention Deficit Disorder: Criteria, cognition, intervention* (pp. 65-82). New York: Pergamon Press.

Douglas, V. I. (1999). Cognitive control processes in attention-deficit/hyperactivity disorder. In H. C. Quay (Ed.), *Handbook of disruptive behavior disorders* (pp. 105-138). New York: Kluwer Academic Publishers.

Dunn, L. M., & Dunn, L. M. (1997). *Peabody Picture Vocabulary Test–Third Edition*. Circle Pines, MN: American Guidance Service.

Fergusson, D. M., & Horwood, L. J. (1995). Early disruptive behavior, IQ, and later school achievement and delinquent behavior. *Journal of Abnormal Child Psychology*, *23*, 183-199.

Gathercole, S., & Alloway, T. P. (2008). *Working memory & learning: A practical guide for teachers*. Thousand Oaks, CA: Sage.

Gjone, H., Stevenson, J., & Sundet, J. M. (1996). Genetic influence on parent reported attention related problems in a Norwegian general population twin sample. *Journal of the American Academy of Child & Adolescent Psychiatry*, *35*, 588-596.

Hair, J. F., Anderson, R. E., Tatham, R. L., & Black, W. C. (1998). *Multivariate data analysis* (5th ed.). Upper Saddle River, NJ: Prentice Hall.

Harper, G. W., & Ottinger, D. R. (1992). The performance of hyperactive and control preschoolers on a new computerized measure of visual vigilance: The Preschool Vigilance Task. *Journal of Child Psychology & Psychiatry & Allied Disciplines*, *33*, 1365-1372.

Harris, F. C., & Lahey, B. B. (1982). Recording system bias in direct observational methodology: A review and critical analysis of factors causing inaccurate coding behavior. *Clinical Psychology Review*, *2*, 539-556.

Hollingshead, A. B. (1975). *Four Factor Index of Social Status*. New Haven, CT: Yale University Department of Sociology.

Hooks, K., Milich, R., & Lorch, E. P. (1994). Sustained and selective attention in boys with attention deficit hyperactivity disorder. *Journal of Clinical Child Psychology*, *23*, 69-77.

Jacob, R. G., O'Leary, K. D., & Rosenblad, C. (1978). Formal and informal classroom settings: Effects on hyperactivity. *Journal of Abnormal Child Psychology*, *6*, 47-59.

Kazdin, A. E. (1998). *Research design in clinical psychology* (3rd ed.). Needham Heights, MA: Allyn & Bacon.

Kofler, M. J., Rapport, M. D., & Alderson, R. M. (2008). Quantifying ADHD classroom inattentiveness, its moderators, and variability: A meta-analytic review. *Journal of Child Psychology and Psychiatry*, *49*, 59-69.

Kuntsi, J., Oosterlaan, J., & Stevenson, J. (2001). Psychological mechanisms in hyperactivity: I Response inhibition deficit, working memory impairment, delay aversion, or something else? *Journal of Child Psychology and Psychiatry*, *42*, 199-210.

Leth-Steensen, C., Elbaz, Z. K., & Douglas, V. I. (2000). Mean response times, variability and skew in the responding of ADHD children: A response time distributional approach. *Acta Psychologica*, *104*, 167-190.

Mannuzza, S., Klein, R. G., Bessler, A., Malloy, P., & LaPadula, M. (1993). Adult outcome of hyperactive boys: Educational achievement, occupational rank, and psychiatric status. *Archives of General Psychiatry*, *50*, 565-576.

Marsh, P. J., & Williams, L. M. (2004). An investigation of individual typologies of attention-deficit hyperactivity disorder using cluster analysis of DSM-IV criteria. *Personality and Individual Differences*, *36*, 1187-1195.

McGee, R. A., Clark, S. E., & Symons, D. K. (2000). Does the Conners' continuous performance test aid in ADHD diagnosis? *Journal of Abnormal Child Psychology*, *28*, 415-424.

Nigg, J. T., Hinshaw, S. P., & Halperin, J. M. (1996). Continuous performance test in boys with attention deficit hyperactivity disorder: Methylphenidate dose response and relations with observed behaviors. *Journal of Clinical Child Psychology*, *25*, 330-340.

Pelham, W. E., Fabiano, G. A., & Massetti, G. M. (2005). Evidence-based assessment of attention deficit hyperactivity disorder in children and adolescents. *Journal of Clinical Child and Adolescent Psychology*, *34*, 449-476.

Pelham, W. E., Milich, R., & Walker, J. L. (1986). Effects of continuous and partial reinforcement and methylphenidate on learning in children with attention deficit disorder. *Journal of Abnormal Psychology*, *95*, 319-325.

Power, T. J. (1992). Contextual factors in vigilance testing of children with ADHD. *Journal of Abnormal Child Psychology*, *20*, 579-593.

Rapport, M. D., Alderson, R. M., Kofler, M. J., Sarver, D. E., Bolden, J., & Sims, V. (2008). Working memory deficits in attention-deficit/hyperactivity disorder (ADHD): The contribution of central executive and subsystem processes. *Journal of Abnormal Child Psychology*, *36*, 825-837.

Rapport, M. D., Chung, K. M., Shore, G., Denney, C. B., & Issacs, P. (2000). Upgrading the science and technology of assessment and diagnosis: Laboratory and clinic-based assessment of children with ADHD. *Journal of Clinical Child Psychology*, *29*, 555-568.

Rapport, M. D., Chung, K. M., Shore, G., & Issacs, P. (2001). A conceptual model of child psychopathology: Implications for understanding attention deficit hyperactivity disorder and treatment efficacy. *Journal of Clinical Child Psychology*, *30*, 48-58.

Rapport, M. D., Denney, C., DuPaul, G. J., & Gardner, M. J. (1994). Attention deficit disorder and methylphenidate: Normalization rates, clinical effectiveness, and response prediction in 76 children. *Journal of the American Academy of Child & Adolescent Psychiatry*, *33*, 882-893.

Rapport, M. D., Kofler, M., Alderson, M., & Raiker, J. (2008). Attention-Deficit/Hyperactivity Disorder. In M. Hersen & D. Reitman (Eds.), *Handbook of psychological assessment, case conceptualization and treatment, Volume 2: Children and adolescents* (pp. 349-404). Hoboken, NJ: Wiley & Sons.

Rapport, M. D., Scanlan, S. W., & Denney, C. B. (1999). Attention-deficit/hyperactivity disorder and scholastic achievement: A model of dual developmental pathways. *Journal of Child Psychology and Psychiatry*, *40*, 1169-1183.

Rasmussen, E. R., Neuman, R. J., Heath, A. C., Levy, F., Hay, D., & Todd, R. D. (2004). Familial clustering of latent class and DSM-IV defined attention-deficit/hyperactivity disorder (ADHD) subtypes. *Journal of Child Psychology and Psychiatry*, *45*, 589-598.

Routh, D. K., Schroeder, C. S., & O'Tuama, L. (1974). Development of activity level in children. *Developmental Psychology*, *10*, 163-168.

Seidel, W. T., & Joschko, M. (1991). Assessment of attention in children. *Clinical Neuropsychologist*, *5*, 53-66.

Sergeant, J. A., Oosterlaan, J., & van der Meere, J. (1999). Information processing and energetic factors in attention-deficit/hyperactivity disorder. In H. C. Quay & A. E. Hogan (Eds.), *Handbook of disruptive behavior disorders* (pp. 75-104). Dordrecht, The Netherlands: Kluwer Academic Publishers.

Sonuga-Barke, E. J. S. (2002). Interval length and time-use by children with AD/HD: A comparison of four models. *Journal of Abnormal Child Psychology*, *30*, 257-264.

Swaab-Barneveld, H., de Sonneville, L., Cohen-Kettenis, P., Gielen, A., Buitelaar, J., & van Engeland, H. (2000). Visual sustained attention in a child psychiatric population. *Journal of the American Academy of Child & Adolescent Psychiatry*, *39*, 651-659.

Todd, R. D., Rasmussen, E. R., Neuman, R. J., Reich, W., Hudziak, J. J., Bucholz, K. K., et al (2001). Familiality and heritability of subtypes of attention deficit hyperactivity disorder in a population sample of adolescent female twins. *American Journal of Psychiatry*, *158*, 1891-1898.

Todd, R. D., Sitdhiraksa, N., Reich, W., Ji, T. H., Joyner, C. A., Heath, A. C., et al. (2002). Discrimination of DSM-IV and latent class attention-deficit/hyperactivity disorder subtypes by educational and cognitive performance in a population-based sample of child

and adolescent twins. *Journal of the American Academy of Child & Adolescent Psychiatry*, *41*, 820-828.

Vaessen, W., & van der Meere, J. J. (1990). Issues in the selection of hyperactive/ADD(H) children for experimental clinical studies. In A. F. Kalverboer (Ed.), *Developmental biopsychology: Experimental and observational studies in groups "at risk"* (pp. 21-37). Ann Arbor: University of Michigan Press.

van der Meere, J. J., Shalev, R., Börger, N., & Gross-Tsur, V. (1995). Sustained attention, activation and MPH in ADHD: A research note. *Journal of Child Psychology and Psychiatry*, *36*, 697-703.

Weis, R., & Totten, S. J. (2004). Ecological validity of the Conners' Continuous Performance Test II in a school-based sample. *Journal of Psychoeducational Assessment*, *22*, 47-61.

Whalen, C. K., Collins, B. E., Henker, B., Alkus, S. R., Adams, D., & Stapp, J. (1978). Behavior observations of hyperactive children and methylphenidate (Ritalin) effects in systematically structured classroom environments: Now you see them, now you don't. *Journal of Pediatric Psychology*, *3*, 177-187.

Wilson, M. S., & Reschly, D. J. (1996). Assessment in school psychology training and practice. *School Psychology Review*, *25*, 9-23.

World Health Organization. (1993). *The ICD-10 classification of mental and behavioural disorders: Diagnostic criteria for research*. Geneva, Switzerland: World Health Organization.

Zentall, S. S. (1993). Research on the educational implications of attention deficit hyperactivity disorder. *Exceptional Children*, *60*, 143-153.

Zentall, S. S., & Meyer, M. J. (1987). Self-regulation of stimulation for ADD-H children during reading and vigilance task performance. *Journal of Abnormal Child Psychology*, *15*, 519-536.

Mark D. Rapport, PhD, is a professor of clinical psychology and director of the Children's Learning Clinic-IV in the Department of Psychology at the University of Central Florida. His research interests focus on examining the nascent working memory model of ADHD, core deficits of ADHD, and the complex interplay between cognition and behavior.

Michael J. Kofler, MS, is currently a doctoral student in the Department of Psychology at the University of Central Florida. His current research interests include understanding the influence of working memory on attention in children with ADHD.

R. Matt Alderson, PhD, is an assistant professor in the Department of Psychology at Oklahoma State University. His current research interests involve understanding behavioral inhibition and other central executive processes in children with ADHD.

Thomas M. Timko, Jr., MS, completed his master's degree training in the Department of Psychology at the University of Central Florida and is currently working in the private sector.

George J. DuPaul, PhD, is a professor of school psychology and chair of the Department of Education and Human Services at Lehigh University. His research interests include school-based interventions for students with ADHD, early intervention for young children with ADHD, and assessment and treatment of ADHD in college students.