PERFORMANCE ON THE FLICKER TASK AND CONNERS' CPT IN CHILDREN WITH ADHD

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PERFORMANCE ON THE FLICKER TASK AND CONNERS' CPT IN CHILDREN WITH ADHD

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A Dissertation
Submitted to
the Graduate Faculty of
Auburn University
in Partial Fulfillment of the
Requirements for the
Degree of
Doctor of Philosophy

Auburn, Alabama
December 18, 2009

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IN CHILDREN WITH ADHD

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DISSERTATION ABSTRACT

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Doctor of Philosophy, December 18, 2009
(M.S., Auburn University, 2005)
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98 Typed Pages

Directed by Steven K. Shapiro

Flicker task performance has not been examined in children, and the Conners' Continuous Performance Test (CCPT) has received little empirical scrutiny related to ADHD compared to CPTs at large. Thus, the present study compared the discriminative utility of Rensink and colleagues' (1997) flicker task and the CCPT to differentiate performance in children with and without ADHD. Flicker task and CCPT performance were compared between an ADHD (n = 33) and control (n = 28) group. Results replicate previous flicker task findings from Rensink et al. (1997) and Cohen and Shapiro (2007), demonstrating the robust nature of change blindness, via the flicker task, across developmental stages. Surprisingly, compared to controls, children with ADHD demonstrated faster reaction time with less variability in detecting the most difficult types of changes, and a hypothesis is offered to account for this unexpected finding. However, results indicate that the flicker task does not demonstrate better discriminative utility compared to the CCPT. Instead, the flicker task and CCPT provide similarly weak discriminative utility, consistent with the CPT literature at large. Significant correlations with dependent measures of the two tasks were frequently common to ADHD rating scale indices of both inattention and hyperactivity/impulsivity, indicating a lack of symptom domain specificity of CPT measures. Recommendations are provided regarding the future study of CPTs as valid measures of ADHD performance and the potential utility of the flicker task.

ACKNOWLEDGMENTS

I wish to thank Steve Shapiro for his guidance, support, and enthusiasm in the development and implementation of my dissertation. More importantly, I thank Steve for providing the nurturing and supportively challenging context that has fostered my personal and professional development. To my committee members—Roger Blashfield, Jen Gillis, and Jeff Katz—I extend great thanks for their valuable input, feedback, and encouragement. Specifically, I thank Roger for fostering my inner DCT, I thank Jen for encouraging me to make the most of my internship experience, and I thank Jeff for encouraging me to take confident ownership of my knowledge. I also wish to thank Joe Buckhalt for his time and energy in serving as my outside reader. I extend my thanks and appreciation to Ron Rensink for granting me use of his flicker task stimuli. To Team Shapisk—Sarah Peden, Bill Ferguson, and Clarissa Mooney—I most appreciate having worked with such a capable and fun research team. In particular, thanks to Sarah for your expert collaboration as well as your stewardship in my absence, thanks to Bill for carrying the torch of "good guy with great promise who gives Steve a hard time," and thanks to Clarissa for jumping right in and becoming a valuable team member. To Lauren Coursen and Andrew Kunzel, I earnestly give thanks for their dedication to excellence as my trusty research assistant and software programmer, respectively. Thanks are due to the myriad schools and community health providers for their assistance in recruiting participants. Thanks to the various Auburn faculty and graduate student colleagues who

have helped me along the way. Also, many thanks to my internship supervisors for supporting my dissertation needs. Thank you to the various funding sources—Brown Finch Foundation, Graduate School, Psych dept—that made this research possible. And a sincere thank you to the kiddos and families who give meaning to the data.

To my family, I express my sincere respect, appreciation, gratitude, and love. You are my rock, and my development as a person and a professional is built firmly on the secure foundation that you provide. I especially wish to thank Mom and Dad for providing me with their infinite wisdom, unwavering support, and unconditional love. Mom, love and a hug. Dad, I think you know all that you do for me. Last and certainly not least, Jenler, I do not tell you often enough how proud I am of you. With love, I am.

Style manual used:

APA Publication Manual (5th edition)

Computer software used:

E-Prime 1.3
Mac OS X (v. 10.5.7)
Microsoft Excel (2008 for Mac, XP for Windows)
Microsoft Word (2008 for Mac, XP for Windows)
Microsoft Windows XP (SP2)
SPSS 16.0 (for Mac and Windows)

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INTRODUCTION

Attention-Deficit/Hyperactivity Disorder (ADHD)

ADHD is one of the most commonly diagnosed childhood disorders, with a range of prevalence estimates depending on the source. The current *Diagnostic and Statistical Manual of Mental Disorders* (4th ed., text revision [*DSM-IV-TR*]; American Psychiatric Association, 2000), which utilized a host of studies conducted in the 1980s and 1990s that employed current and previous *DSM* diagnostic criteria, estimates prevalence at 3 to 7%. In comparison, an independent meta-analysis examining studies that used only *DSM-IV* diagnostic criteria offered a range of 8 to 12% (Faraone, Sergeant, Gillberg, & Biederman, 2003). ADHD in childhood exhibits male overrepresentation of approximately three to one and frequently persists into adulthood (Barkley, 2006). Prevalence estimates for ADHD in adulthood are 4.1% in the United States (Kessler, Chiu, Demler, & Walters, 2005) and 0.6 to 1.6% in Europe (Kooij et al., 2005).

ADHD is characterized along two symptom domains, inattention-disorganization and hyperactivity-impulsivity, which yield three clinical subtypes: Predominantly Inattentive (ADHD-I), Predominantly Hyperactive-Impulsive (ADHD-H), and Combined (ADHD-C; American Psychiatric Association, 2000). Individuals with ADHD have significant difficulty in the areas of attention, response inhibition, and self-regulation (Barkley, 1997). In adults diagnosed with ADHD, problems with impulsivity and inattention continue, although visible motoric restlessness and overactivity decrease while subjective restlessness and fidgetiness persist (Barkley, 2006; Hinshaw & Zalecki, 2001). The negative consequences of ADHD symptomatology are diverse and cumulative: ADHD is associated with greater risk for low academic achievement, poor peer and family relations, mental disorders (e.g., anxiety and depression), conduct problems, and difficulties in friendships, marriages, and employment (Barkley, 2006).

Mental health care professionals currently debate the true nature and underlying mechanisms of ADHD and its subtypes (e.g., Barkley, 1997, 2006; Biederman & Faraone, 2005; Hinshaw & Zalecki, 2001; Nigg, 2006; Span, Earleywine, & Strybel, 2002). Multidisciplinary research has provided extensive support that dysregulation in the prefrontal cortex commonly (although not universally) operates in individuals with ADHD, leading to deficits in executive functioning (e.g., behavioral inhibition, sustained attention, working memory; Barkley, 2006; Biederman & Faraone, 2005). Indeed, ADHD is associated with deficits in executive neuropsychological tasks, with effect sizes (d) averaging 0.59 compared to control groups (Frazier, Demaree, & Youngstrom, 2004). Researchers have offered various theories of what constitutes the primary dysregulation in the prefrontal cortex, including deficits in brain systems mediating inhibitory control, reward and response cost, and arousal, activation, and effortful control (Biederman & Faraone, 2005; Nigg, 2006). Regardless of the various mechanisms proposed to underlie ADHD and its subtypes—and given that current research largely rejects inattention as such an underlying mechanism—the fact remains that the behavioral presentations of all three ADHD subtypes share the consequence of inattention (Barkley, 2006). That is, individuals with ADHD display difficulties with attention relative to same-age and gendered peers (Barkley, 2006).

The Continuous Performance Test

ADHD symptoms are most commonly assessed using the clinical interview, rating scales, and a medical evaluation (Barkley, 2006). However, laboratory measures designed to measure attention and impulsivity in a more objective manner have been explored as potentially useful discriminative assessment devices (Barkley, 2006; Riccio, Reynolds, & Lowe, 2001). One of the most popular laboratory measures is the Continuous Performance Test (CPT; Epstein, Conners, Sitarenios, & Erhardt, 1998; McGee, Clark, & Symons, 2000; Nichols & Waschbusch, 2004; Riccio et al., 2001). In general, CPTs require observers to maintain vigilance and react (or not) to the presence or absence of a specific stimulus within a set of continuously presented distracters. Literature examining CPT performance in children has been extensive, although there is a dearth of research concerning CPT performance in adults (Cohen & Shapiro, 2007; Epstein et al., 1998; Solanto, Etefia, & Marks, 2004). Current research has produced equivocal results regarding the diagnostic utility of CPTs (Hervey, Epstein, & Curry, 2004; Nichols & Waschbusch, 2004; Riccio et al., 2001). Inconsistent results abound in both child and adult studies of CPT performance due to the existence of multiple CPT paradigms (e.g., task demands and parameters) and varying research methodologies (e.g., clinical vs. community samples, inclusionary criteria, statistical analyses; Cohen & Shapiro, 2007; Edwards et al., 2007; Epstein et al., 2003; Riccio et al., 2001). Overall, CPTs exhibit moderate *specificity*—ability to detect the absence of attentional and impulsive difficulties—but weak *sensitivity*—ability to identify and differentiate among disorders associated with such difficulties (Barkley, 2006; Epstein et al., 1998; Nichols & Waschbusch, 2004; Riccio et al., 2001).

One of the most widely used commercial CPTs is the Conners' Continuous Performance Test II (CCPT; Conners & MHS Staff, 2002; Riccio et al., 2001). The CCPT is a computerized visual task that requires the individual to press the spacebar for every letter presented except the letter X. Specific to ADHD, child and adult studies of CCPT diagnostic utility report moderate specificity and weak sensitivity and (Cohen & Shapiro, 2007; Edwards et al., 2007; Epstein et al., 1998; Hervey et al., 2004; McGee et al., 2000; Roy-Byrne et al., 1997; Solanto et al., 2004). Although the CCPT may provide some utility for identifying problems with attention and/or impulsivity and helping to diagnose ADHD, there currently exists no gold standard measure for making a differential diagnosis of ADHD (Barkley, 2006; Hervey et al., 2004). However, attempts to characterize individuals into more clinically homogeneous groups and develop more mechanism-specific measures are currently underway (Barkley, 2006; Nigg, 2006).

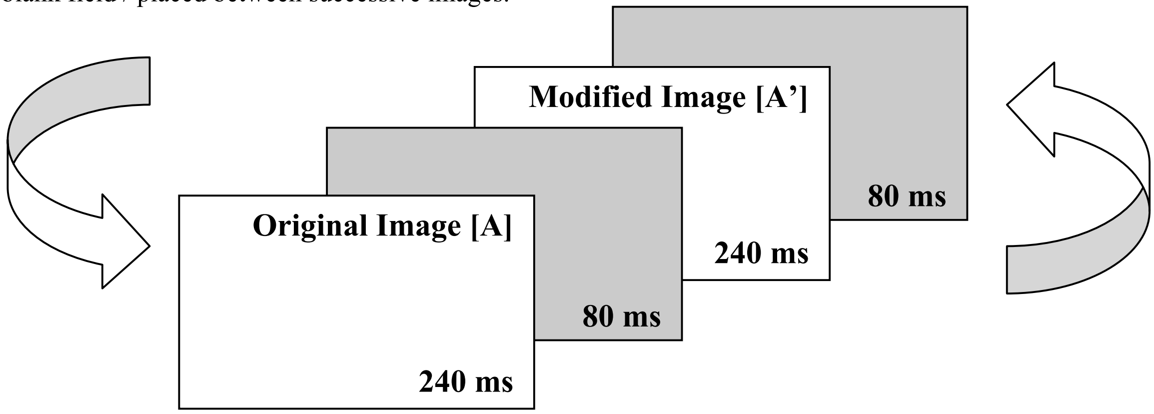
Change Blindness and the Flicker Task

Recent research on visual memory has demonstrated that people are surprisingly poor at detecting large changes in the environment from one moment to the next (e.g., Simons & Levin, 1997). Under normal viewing conditions, changes to a scene generate a motion signal—an automatic, internal cue signifying a visual change—that may be readily detected. However, when another event coincides with a change to a scene, this additional event disrupts the motion signal such that observers are often blind to unexpectedly large changes (Simons, 2000), a phenomenon termed *change blindness*.

Research has demonstrated the ecological validity of change blindness, such that change blindness has been demonstrated during a variety of increasingly naturalistic experimental paradigms: movie cuts—the shift in successive camera positions (Levin & Simons, 1997); real-world occlusion events—when a person's view is blocked during an in vivo interaction (Simons & Levin, 1998); saccades—the small jerky movement of the eye as it jumps from one fixation point to another (Grimes, 1996); and eye blinks (O'Regan, Deubel, Clark, & Rensink, 2000).

To examine change blindness, Rensink, O'Regan, and Clark (1997) developed the flicker task. In this paradigm, an original image [A] repeatedly alternates with a modified image [A'], with a blank field placed between successive images (see Figure 1; also see Rensink et al., 1997). An example of an image modification is the alternating location of an object within a scene. The observer freely views the flickering display, presses a key when the change is perceived, and must then correctly describe the change. A key result of Rensink et al.'s (1997) work provides support for the role of attention in the flicker task and, more generally, in the change blindness phenomenon. Observers more rapidly detected changes to central interest than marginal interest objects. Central interest objects capture the theme of the scene (e.g., the meal enjoyed by a couple dining out), whereas

Figure 1. The flicker task. An original image [A] repeatedly alternates with a modified image [A'], with a blank field / placed between successive images.



marginal interest objects do not (e.g., the horizon level behind the dining couple). The argument follows that the salience or thematic centrality of central interest objects makes them more "interesting" than marginal interest objects. Researchers have posited the attentional mechanism that more "interesting" items gain increased or prioritized attention, which leads to more rapid change detection (O'Regan et al., 2000; Rensink et al., 1997; Simons, 2000).

Change blindness researchers have concluded that *focused attention* is necessary for change detection (e.g., Mitroff & Simons, 2002; O'Regan et al., 2000; Simons, 2000). Focused attention is the process by which an individual attempts to track one stimulus (or one type of stimulus) and ignore another, a process that typically involves both search and vigilance (Sternberg, 1999). If observers could encode an entire scene with a single attentional fixation—that is, use a parallel search—they could detect changes anywhere in an image with equal ability. However, the change blindness phenomenon demonstrates clearly that observers do not use parallel search. Instead, observers must serially scan a scene, placing focused attention on salient items first and encoding the scene piecemeal (Rensink et al., 1997). The flicker task is an intentional change detection task in that observers know that changes will occur and actively search the display to find them. Surprisingly, observers are change blind even when their primary task is to attend to and search for changes (Cohen & Shapiro, 2007; Rensink et al., 1997; Simons, 2000). In short, change blindness is conceptualized as a phenomenon of attentional processing, and the flicker task is a measure used to examine it.

Rationale for the Current Study

Change blindness research has been restricted largely to establishing the robust nature of the phenomenon itself (Grimes, 1996; Levin & Simons, 1997; O'Regan et al., 2000; Rensink et al., 1997; Simons & Levin, 1998). Few studies have applied the implications of change blindness to a clinical population (e.g., Burack et al., 2009; Cohen & Shapiro, 2007; Jones, Jones, Smith, & Copley, 2003; McGlynn, Wheeler, Wilamowska, & Katz**,** 2008). In a recent study by Cohen and Shapiro (2007), the central role of attention in change blindness provided impetus for investigating the phenomenon of change blindness in college-age adults with ADHD. Given that individuals with ADHD exhibit attentional difficulties compared to peers (Barkley, 2006), ADHD, as a disorder associated with attentional difficulties, is suitable for investigation with an attention-oriented measure, the flicker task.

Cohen and Shapiro (2007) examined the ability of the flicker task to demonstrate greater utility than the CCPT in discriminating performance in young adults with and without ADHD, whereby they compared flicker task and CCPT performance between an ADHD (n = 28) and control (*n* = 30) group of college students. Results replicated previous flicker task findings that central-interest changes are detected more rapidly than marginal-interest changes (e.g., Rensink et al., 1997). Results also yielded significant group differences for both tasks, such that the ADHD group demonstrated poorer accuracy (greater commission errors) in the flicker task and poorer accuracy (greater commission errors and poorer d') and greater variability (increased variability of reaction time overall and for the different ISI conditions) in the CCPT. However, the flicker task did not demonstrate better discriminative utility than the CCPT. Instead, consistent with the child and adult CCPT literature (Edwards et al., 2007; Epstein et al., 1998; Hervey et al., 2004; McGee et al., 2000; Riccio et al., 2001; Solanto et al., 2004), both measures provided generally weak discriminative ability regarding adults with and without ADHD, with sensitivity and specificity of 57% and 87% for the flicker task and 71% and 77% for the CCPT. Also, various flicker task and CCPT dependent variables correlated with ADHD rating scale indices of both inattention and hyperactivity/impulsivity, supporting prior research that CPTs lack symptom domain specificity (Edwards et al., 2007; Epstein et al., 1998; Epstein et al., 2003; McGee et al., 2000; Solanto et al., 2004).

Despite the growing evidence that CPTs (including the CCPT) currently provide only modest utility for discriminating performance in children and adults with and without ADHD (Edwards et al., 2007; Epstein et al., 1998; Hervey et al., 2004; Nichols & Waschbusch, 2004; Riccio et al., 2001; Solanto et al., 2004), there is substantial rationale for extending Cohen and Shapiro's (2007) comparison of the flicker task and CCPT in adults to children with ADHD. First, no studies have examined change blindness or flicker task performance in children. Change blindness and the flicker task have received considerable empirical attention in adults, and extending this line of research to children will facilitate a developmental understanding of change blindness and the flicker task.

Second, there are relatively few CCPT-specific studies that focus on its validity in children (Conners, Epstein, Angold, & Klaric, 2003; Edwards et al., 2007; Epstein et al., 2003; McGee et al., 2000; Shaw, Grayson, & Lewis, 2005) and adults (Cohen & Shapiro, 2007; Epstein et al., 1998; Epstein, Johnson, Varia, & Conners, 2001; Kovner et al., 1998; Murphy, Barkley, & Bush, 2001; Roy-Byrne et al., 1997; Solanto et al., 2004; Walker, Shores, Troller, Lee, & Sachdev, 2000) compared to the substantial number of studies pertaining to other CPT variants (for a review, see Riccio et al., 2001). As noted earlier, given the differences in CPT paradigms and research methodology, comparing results across CPT studies is difficult enough, let alone comparing CCPT studies to results from CPT research at large. Therefore, considering that the CCPT is used so widely in clinical child settings (Conners et al., 2003; Epstein et al., 2003; Riccio et al., 2001), further research regarding CCPT performance and utility in children is warranted.

Third, building upon the established ecological validity of change blindness as a phenomenon, the use of environmentally realistic stimuli in the flicker task (photographs of real-world scenes) is posited to offer superior ecological validity compared to the stimuli in the CCPT (the presentation of letters). This rationale served as partial motivation in Cohen and Shapiro's (2007) comparison of the flicker task and CCPT in adults, although the flicker task's environmentally realistic stimuli did not serve to improve its discriminative utility over that of the CCPT. Nevertheless, compared to the relative simplicity of detecting target letters in the CCPT, the complexities of detecting change in the flicker task's real-world scenes may prove sufficiently challenging to children with ADHD, which may enhance the flicker task's ability to discriminate children with and without ADHD compared to the CCPT.

Variables and Hypotheses for the Current Study

Cohen and Shapiro's (2007) comparison of the flicker task and CCPT in adults with and without ADHD was extended to a child sample. The current study examined the ability of the flicker task to demonstrate greater utility in discriminating performance in children with and without ADHD compared to the CCPT. Flicker task and CCPT performance were compared between an ADHD and a non-ADHD comparison (hence "control") group. Parallel dependent variables were used for the two tasks: the number of cycles needed to detect change (i.e., reaction time (RT), such that one cycle represents a single alternation of images: original image [A], blank screen, modified image [A'], blank screen; see Figure 1), variability of cycles, and accuracy (commission and omission errors) for the flicker task; and RT, variability of RT, and accuracy (commission and omission errors) for the CCPT.

For the flicker task, diagnostic group differences were predicted, with the ADHD group expected to produce a greater number of cycles, greater variability of cycles, and lower accuracy compared to the control group. A within-subjects main effect was also predicted, with the expectation to replicate previous findings that observers more rapidly detect central than marginal interest changes (Cohen & Shapiro, 2007; Rensink et al., 1997).

For the CCPT, diagnostic group differences were predicted. Most CCPT studies in children (Epstein et al., 2003; Shaw et al., 2005) and adults (Epstein et al., 1998; Murphy et al., 2001; Walker et al., 2000) have found that individuals with ADHD generate more omission and commission errors and greater variability of RT compared to controls, with some studies including mixed results (Cohen & Shapiro, 2007) and exceptions to these trends (Epstein et al., 2001; Kovner et al., 1998; McGee et al., 2000). Hypotheses for the current study paralleled the majority of prior CCPT findings, with differences expected between the ADHD and control group. Also, compared to CCPT performance, flicker task performance was hypothesized to generate better clinical sensitivity and specificity. Of note, a limitation of sensitivity and specificity is that these values do not account for the prevalence of a diagnosis. Thus, Elwood (1993) suggested reporting *positive predictive power*—the proportion of individuals with positive test results that is diagnosed correctly—and *negative predictive power*—the proportion of individuals with negative test results that is diagnosed correctly—values that can account for prevalence. In this manner, flicker task performance is hypothesized to generate better positive and negative predictive power.

The relationship of dependent variables among the flicker task, CCPT, and ADHD parent-report ratings scales was examined. Specifically, clinical assumptions have fostered various CPT-behavior links—omission errors reflect attention problems and commission errors reflect hyperactivity and impulsivity—although CCPT research attempting to confirm these relationships has generated either weak and conflicting results (Cohen & Shapiro, 2007; Edwards et al., 2007; Epstein et al., 1998, 2003; McGee et al., 2000; Solanto et al., 2004; Weis & Totten, 2004). The current study extended the literature's continued examination of these hypothesized relationships for both the CCPT and flicker task. Consistent with the trend established in prior research, elevated ratings of attention problems and hyperactivity/impulsivity were not expected to correlate in a domain-specific manner with increased omission and commission errors, respectively. Also, CCPT research suggests that children and adults with and without ADHD do not differ in RT (Epstein et al., 1998, 2003; Murphy et al., 2001; Roy-Byrne et al., 1997; Solanto et al., 2004; Walker et al., 2000), such that rating scale results were not expected to correlate with CCPT RT. However, the hypothesized increased demands of the flicker task were predicted to challenge children with ADHD compared to children without ADHD, whereby ratings scale results were expected to correlate with flicker task number of cycles. That is, elevated ratings of attention problems and hyperactivity were expected to be associated with greater number of cycles (slower detection) on the flicker task.

Developmental Considerations Regarding the Flicker Task and Visual Search

Given that the flicker task is a visual search paradigm—and, heretofore, research using the flicker task has not included a child population—it is important to provide a brief review of relevant normative and developmental findings from the visual search literature. Stemming from the seminal work by Treisman and Gelade (1980), a well-established framework for visual search includes the dichotomy of “easy” and “difficult” searches. An “easy” search for targets that “pop out” is characterized as involving “automatic” or “parallel” processing, whereas a “difficult” search for targets that are not readily identified is characterized as involving “effortful” or “serial” processing. Specific to the flicker task, the less demanding task of detecting central interest changes may be considered an automatic or parallel process, whereas the more challenging task of detecting marginal interest changes may be considered an effortful or serial process.

Visual search findings indicate that both children and adults are able to conduct parallel and serial searches. However, visual search RT improves with age for children ages 6 to 12 years old, such that 6- to 8-year-old children typically are the slowest to identify targets in both parallel and serial searches. Additionally, 6- to 8-year-old children tend to make more errors (i.e., miss more targets) as the level of search complexity increases. Given these age-related performance differences for visual search, efforts were taken in the current study to account for any age-related effects on the flicker task. Specifically, the visual search task (VST)—used by Lobaugh, Cole, and Rovet (1998) and derived from Treisman (1991)—is a computerized task designed to measure visual processing (i.e., both parallel and serial search). Observers search for the target (i.e., vertical blue bar) among a display of distractors and respond when they determine the target to be present or absent. The VST was selected and administered in order to identify an age-related performance variable that would serve as a suitable covariate in flicker task analyses.

METHOD

Participants

To recruit children with and without ADHD, flyers were distributed in the offices of local psychologists, mental health clinicians, physicians, in elementary schools and daycare centers, and to sports groups and professional/parent advocacy organizations. In addition, recruitment utilized the "snowball" technique in which parents of children who participated in the study were asked to distribute flyers and recruitment packets to other parents with children in the age range of interest. A child age range limit of 6 to 12 years (i.e., approximately first to sixth grade) was established to (a) address the population that seeks the majority of therapeutic services for ADHD (Barkley, 2006) and (b) control for some potential developmental differences (i.e., exclude preschoolers and teenagers). A priori power analyses indicated that two groups of 34 children with and without ADHD would secure adequate statistical power. A priori power analyses were conducted utilizing *G*Power 3* software, a free statistical package that has gained popularity in the behavioral sciences and earned acclaim within the last 10 years (Faul, Erdfelder, Lang, & Buchner, 2007). Of note, the power analyses employed standard values of coefficient alpha (.05), power (.80), and medium effect size (e.g., .5 when comparing means, .25 when conducting an ANOVA or MANOVA, .3 when comparing a correlation to the null hypothesis), as established by theory and in practice (Cohen, 1992). The principal investigator obtained approval from Auburn University's Institutional Review Board.

Screening for children with and without ADHD utilized a demographic questionnaire (Appendix A) and the Conners' Parent Rating Scales-Revised, Long Form (CPRS; Conners, 1997), a norm-referenced diagnostic questionnaire based on *DSM-IV* ADHD criteria. Inclusion criteria for the ADHD group required one parent/legal guardian to: (a) endorse a current established ADHD diagnosis for the child, with or without past or current use of psychostimulant medication; (b) complete the CPRS such that scores met or exceeded 1.5 standard deviations above the mean for the *DSM-IV Inattentive Symptoms Scale* and/or the *DSM-IV Hyperactive-Impulsive Symptoms Scale*; and (c) deny current use of any psychoactive medication (other than psychostimulants) for the child. For children with current or past history of psychostimulant medication for ADHD, parents/guardians were instructed to respond to the CPRS regarding their child's off-medication behavior. Logistical issues regarding the recruitment of a satisfactory ADHD sample size precluded more specific inclusion/exclusion criteria. Therefore, children with ADHD were not excluded based on ADHD subtype (as defined by CPRS ratings) or history of other psychological disorders (other than uncorrected visual impairment, seizures, psychosis, and documented brain damage).

Inclusion criteria for the control group required one parent/guardian to: (a) deny past and current history of an established ADHD diagnosis for the child; (b) complete the CPRS, such that scores did not exceed 1 standard deviation above the mean for the *DSM-IV Inattentive Symptoms Scale* or the *DSM-IV Hyperactive-Impulsive Symptoms Scale*; and (c) deny current use of any psychoactive medication for the child. Children in the control group were not excluded based on past or current history of psychological disorders (other than uncorrected visual impairment, seizures, psychosis, and documented brain damage).

Importantly, a recent review by Pelham, Fabiano, and Massetti (2005) regarding evidence-based best assessment practices for ADHD noted that research on ADHD rating scales has used maternal parent report almost exclusively, thereby limiting the generalization of diagnostic utility regarding fathers or paternal guardians. Therefore, maternal parents/guardians were requested to complete the CPRS whenever possible, with paternal parents/guardians asked to complete the CPRS in the absence of a maternal report. Also, best ADHD assessment practices vary depending on the clinical or research purpose. Whereas assessment for clinical application calls for a comprehensive evaluation in order to assess for both ADHD symptomatology and functional impairment, assessment for research purposes requires only a *DSM*-based diagnostic scale in order to establish the diagnosis for inclusion in the study (Pelham et al., 2005). Moreover, no incremental validity or utility is conferred by structured interviews when parent ratings are utilized, the utility of combining parent and teacher report to establish a diagnosis is currently unknown, and child self-reports are not valid for diagnostic purposes (Pelham et al., 2005). Therefore, the above concerns provided the rationale for using only parent/guardian (and preferably maternal) report to screen for ADHD in the present study.

Thirty-three children with ADHD and twenty-eight children without ADHD met study criteria and completed the study. Of the 33 children with ADHD, 3 met CPRS criteria for ADHD-H, 3 for ADHD-I, and 27 for ADHD-C. Participants were matched as best as possible for age and sex, with no difference between the ADHD and Control group in age, $t(59) = 0.60$, $p > .05$, or proportion of sex, $t(59) = -1.25$, $p > .05$. The ADHD group included 26 males and 7 females, with a mean age of 9.42 years (*SD* = 1.71); the control group included 18 males and 10 females, with a mean age of 9.14 years (*SD* = 1.98). The majority of participants in the ADHD and Control groups were Caucasian, but there was a difference in proportion of race (regarding Caucasian and African-American representation) between the two diagnostic groups, $t(58) = 3.98$, $p < .001$. All participants in the control group were Caucasian but one child (African American), whereas the ADHD group included 18 Caucasian children, 14 African American children, and 1 Asian American child. However, the two subsets of Caucasian and African American children in the ADHD group yielded no differences in performance across any experimental task variables. Of the 33 children with ADHD, 25 (75.76%) reported current use of ADHD medication: 7 (28.0%) using Concerta, 4 (16.0%) using Adderall XR, 3 (12.0%) using Focalin, 3 (12.0%) using Metadate CD, 3 (12.0%) using Vyvanse, 2 (8.0%) using Metadate, 1 (4.0%) using Adderall, 1 (4.0%) using Daytrana, 1 (4.0%) using Methylphenidate, and 1 (4.0%) using Ritalin LA. Total *n* and percentage sums to greater than 25 and 100%, respectively, because 1 of the 25 children with ADHD reported using two ADHD medications. Mean CPRS responses of the diagnostic groups differed significantly for all scales, such that parents of children with ADHD reported greater ADHD symptoms and related difficulties, $F(14, 45) = 37.21$, $p < .001$ (Table 1).

Table 1. CPRS Scores and Group Comparison

	ADHD Group (*n* = 33)		Control Group (*n* = 28)		
Scale	*M*	*(SD)*	*M*	*(SD)*	*F*
Oppositional	69.73	(14.13)	48.93	(9.22)	47.22**
Cognitive Problems/Inattention	72.15	(9.07)	47.82	(6.62)	134.40**
Hyperactivity	78.36	(12.96)	46.68	(4.11)	167.56**
Anxious-Shy	61.61	(13.71)	45.11	(4.39)	36.63**
Perfectionism	56.48	(12.83)	46.07	(6.37)	15.46**
Social Problems	65.73	(14.97)	48.96	(6.94)	28.20**
Psychosomatic	59.88	(17.46)	50.43	(10.81)	6.03*
Conners' ADHD Index	76.27	(6.54)	45.75	(4.79)	407.72**
Conners' Global Index: Restless-Impulsive	75.45	(10.92)	46.93	(5.33)	154.45**
Conners' Global Index: Emotional Lability	66.73	(14.96)	48.29	(8.52)	31.49**
Conners' Global Index: Total	74.03	(12.13)	47.14	(5.84)	124.39**
DSM-IV: Inattentive	74.48	(7.36)	46.57	(5.60)	261.02**
DSM-IV: Hyperactive-Impulsive	78.97	(11.37)	47.18	(4.56)	198.48**
DSM-IV: Total	79.16	(7.90)	46.61	(5.16)	345.63**

Note. CPRS = Conners' Parent Rating Scales; ADHD = Attention-Deficit/Hyperactivity Disorder; DSM = *Diagnostic and Statistical Manual of Mental Disorders*. All scores refer to T-scores.
*p < .05, **p < .001

Measures

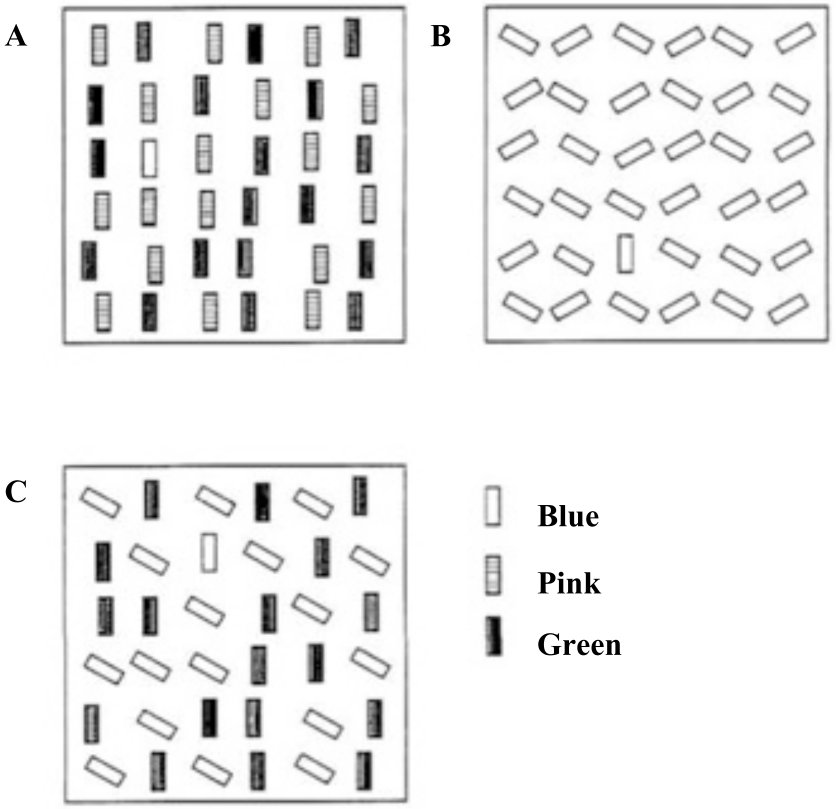
Conners' Parent Rating Scales-Revised, Long Form (CPRS; Conners, 1997). The CPRS, a norm-referenced diagnostic questionnaire based on *DSM-IV* ADHD criteria, assesses core symptoms of ADHD and related problem behaviors in children and adolescents ages 3 to 17. The CPRS is one of the most popular *DSM-IV*-based rating scales and has been used in diverse clinical and research applications (Collett, Ohan, & Myers, 2003; Demaray, Schaefer, & DeLong, 2003). Moreover, recent reviews of evidence-based ADHD assessment have endorsed the CPRS as an excellent rating scale option due to its relevant content and appropriate structure, substantial standardization sample (2,482 children and adolescents), ease of administration and interpretation, and sound psychometric properties (Collett et al., 2003; Demaray, Elting, & Schaefer, 2003).

Studies have reported satisfactory test-retest reliability following an interval of 6 to 8 weeks (coefficients ranged from .73 to .94) and modest to strong internal consistency (Cronbach's alpha coefficients ranged from .47 to .85). Specific to the two scales used to determine inclusion in the present study (i.e., *DSM-IV: Inattentive* and *DSM-IV: Hyperactive-Impulsive*), the CPRS manual reports coefficients for test-retest reliability (.67 and .81, respectively) and internal consistency (6-11 years: .92 to .94 and .85 to .91, respectively; Conners, 1997). The CPRS technical manual provides evidence of validity based on test content, internal structure, convergent and divergent validity, test-criterion relationships, and discriminative ability between youths with and without ADHD (Conners, 1997). Further evidence of validity is provided by a variety of independent studies involving applications of the CPRS to convergent validity for other ADHD scales and measures of externalizing behavior, psychosocial impairment between girls and boys with ADHD, the relationship between ADHD and dopamine D_4 receptor gene, and response to medication treatment (for a brief review, see Collett et al., 2003).

Visual Search Task (VST; Lobaugh et al., 1998; derived from Treisman, 1991). E-Prime software presented stimuli on a Windows desktop computer (17 in (43.18 cm) monitor, 1,024 x 768 resolution, 75 Hz refresh rate). The VST is a computerized task designed to measure visual processing (i.e., both parallel and serial search), derived from a standard paradigm in the visual literature (i.e., Lobaugh et al., 1998; Treisman, 1991). Observers search for the target (i.e., vertical blue bar) among a display of distractors and respond when they determine the target to be present or absent. There are three search conditions (i.e., color, orientation, conjunction of both color and orientation), with three array sizes (i.e., 4, 16, 36) for each search condition. For the color feature search, the distractors are vertical green and pink bars. For the orientation feature search, the distractors are blue bars oriented to the left and right. For the conjunction search, four distractor combinations are possible and utilized (two colors: green/pink and two orientations: left/right). Half of the trials include the target (target-present), and half do not (target-absent). Figure 2 presents examples of 36-item arrays for the three search conditions.

Technical information for the VST is presented as follows. Stimuli consisted of small rectangular bars (1 in) of blue, green, or pink, presented on a black background. Stimuli utilized Corel Draw 5.0 RGB color map values: blue (moderately saturated blue using R102, G153, B255), pink (bluish lavender using R255, G102, B204), and green

Figure 2. The visual search task. Examples of 36-item, target-present (a) color feature, (b) orientation feature, and (c) conjunction searches. Outlines around stimuli and the array were not present in the experiment.



(bluish green using R000, G204, B153). Orientation of the bars varied between vertical or 60^o to left or right of vertical. The stimuli were arranged into square arrays of 4 cells (2x2 array), 16 cells (4x4 array), or 36 cells (6x6 array). Each cell of the array measured 1.25 inches (with the 1-in bar inside the cell). Therefore, the 2x2 array measured 2.5x2.5 in, the 4x4 array measured 5x5 in, and the 6x6 array measured 7.5x.5 in. Although the stimuli were arranged within an array, neither the outline of the cells nor the array was visible to the observer. To reduce reading-like strategies, each stimulus in the array was offset slightly (i.e., jittered) in a vertical and/or horizontal direction. A vertical blue bar was designated as the target for all searches. Each array contained equal number of two distractors. For the color feature search, the distractors were vertical green and pink bars. For the orientation feature search, the distractors were blue bars orientated to the left and right. For the conjunction search, four distracter combinations were possible and utilized (two colors: green/pink crossed by two orientations: right/left). Thus, vertical green or pink bars were paired with blue distracters in one of the two orientations. Specifically, the four conditions were: (1) green vertical bars and left blue bars, (2) green vertical bars and right blue bars, (3) pink vertical bars and left blue bars, and (4) pink vertical bars and right blue bars. Half of the trials included the target (target-present) and half did not (target-absent). On target-present trials, only one target was randomly located within the array. Target and distractor placement was randomly generated per trial, within the constraint that the target appeared equally often in each quadrant at each array size. For each array size, 16 trials ran in each of the two feature conditions (16 trials x 2 feature conditions x 3 array sizes = 96 trials) and 16 trials ran in each of the four conjunction conditions (16 trials x 2 conjunction conditions x 3 array sizes = 192 trials), yielding 288 total trials (96 + 192). Regarding task administration, the “Z” and “?” keys from a standard keyboard collected responses, labeled “Y” (Target Present) or “N” (Target Absent), respectively. Each trial began with a 500-ms warning asterisk in the center of the screen, followed by the array. Each array remained on the screen until a response was made or 10 s had elapsed. The next trial began immediately following each response or after 10 s. Participants received eight practice trials to acquaint themselves with the task. Only practice trials provided feedback: for correct and incorrect responses, respectively, an audio response played “Woohoo!” or “Doh!” (voiced by Homer Simpson).

Flicker Task (Rensink et al., 1997). E-Prime software presented stimuli on a Windows desktop computer (17 in (43.18 cm) monitor, 1,024 x 768 resolution, 75 Hz refresh rate). Flicker sequences included an original image [A], a modified image [A’], and a gray blank field /. Images displayed in the sequence [A] / [A’] / [A] / [A’] and so on, such that a gray blank field appeared between successive images. Each image displayed for 240 ms and each blank screen for 80 ms. The present study included the set of 48 item-pair digitized photographs (each 24.7 x 17.6 cm) of real-world scenes used by Rensink et al. (1997) and Cohen and Shapiro (2007). Six item-pairs comprised the trial set, and 42 item-pairs comprised the stimuli set. Each item-pair contained a single change of presence/absence, color, or location made to an object or area; each change was of either central or marginal interest. Overall, the stimulus set contained central and marginal interest subsets of 21 item-pairs each, with each subset containing seven instances of changes in presence/absence, color, and location. Item-pairs were presented in random order for each participant. Of note, Rensink et al. (1997) established a 1-min time limit, but did not report any instances of failure to identify a change (omission error). However, pilot testing in Cohen and Shapiro's (2007) study indicated a trend toward a considerable number of omission errors, such that a 2-min time limit was established to reduce any excessive frustration experienced by inability to detect the change. Similarly, pilot testing with children demonstrated that a 2-min time was appropriate for the current study. Duration of task administration ranged between 10 to 15 min, depending on participant performance.

Conners' Continuous Performance Test II (CCPT; Conners & MHS Staff, 2002). The CCPT was administered on a Windows desktop computer (17 in (43.18 cm) monitor, 1,024 x 768 resolution, 75 Hz refresh rate), using the standard protocol offered by the software. Three-hundred and sixty letters (approximately 1 in high) appeared on screen, one at a time, for approximately 250 ms. The 360 trials were presented in 18 consecutive blocks of 20 trials, with each block using one of three interstimulus interval (ISI) conditions (1, 2, or 4 s). The ISI conditions were block-randomized across the 18 blocks, such that all three ISI conditions occurred every three blocks. Thus, the protocol was divided into six time blocks consisting of all three ISI conditions. Across ISI and time blocks, the percentage of trials in which letters other than X appeared was 90%. Duration of task administration was 14 min. Split-half reliability for the CCPT measures ranged from .73 to .95 (Conners & MHS Staff, 2002). Test-retest reliabilities for a 3-month interval ranged from .55 to .84 for adults (mean age = 27.7 years) although test-retest reliability was not reported for children (Conners & MHS Staff, 2002).

Independent Variables

Between-Group. For both the flicker task and CCPT, diagnostic group (ADHD versus control group) served as a between-group independent variable. For the flicker task, age group (6-8, 9-10, 11-12 years) served as a between-group independent variable.

Within-Subjects. For the flicker task, degree of interest (central and marginal) and change type (presence/absence, color, and location) served as within-subjects independent variables.

Dependent Variables

VST. Mean RT for target presence (present or absent), search type (color feature, orientation feature, conjunction), and array size (4, 16, 36) served as dependent variables. Also, errors of omission and commission for target presence, search type, and array size served as dependent variables. Of importance, candidate VST covariates for the flicker task included only dependent variables that yielded age and/or diagnostic group differences. Covariate analyses appear in the results section below.

Flicker Task. Mean number of cycles needed to detect change, variability (standard deviation) of mean number of cycles, and accuracy served as dependent variables. Mean number of cycles was calculated for: the average across all stimuli; the levels of degree of interest (central and marginal); the levels of change type (presence/absence, color, and location); and the six stimulus types resulting from crossing the levels of degree of interest by change type. Variability was defined as: the respective standard deviations for the abovementioned means; the change in cycles across the duration of the test (generated by dividing the flicker task into six blocks of seven item-pairs, to mirror the CCPT time block organization, and calculating means and standard deviations per time block); and the change in accuracy across the duration of the test (generated by calculating the means and standard deviations of errors per time block). Accuracy was defined as: the failure to identify a change (omission error); and the incorrect identification of a change (commission error). Accuracy also served as a manipulation check to ensure that participants did not falsely report having detected the change. Averages and standard deviations for mean number and variability of cycles excluded incorrect responses.

CCPT. This task provided a host of normed measures based on the performance of 1,920 nonclinical standardization sample participants, of which 740 were between the ages of 6 and 11 (Conners & MHS Staff, 2002). The CCPT yielded T-scores for omission and commission errors, signal detection parameters, and RT. The average speed of all target responses for the entire test (Hit RT) served as an overall response time measure. Dependent variables for variability included: the standard error of Hit RT (Hit RT SE); a measure of “within-respondent” variability, which compared the variability of 18 time blocks to the overall variability, Hit RT SE (Variability); the change in RT across the duration of the test (Hit RT Block Change) and its associated standard error (Hit SE Block Change); the change in mean RT for the different ISIs of 1, 2, and 4 s (Hit RT ISI Change) and its associated standard error (Hit SE ISI Change); and an indicator of either unusually slow, random, or anticipatory responding, or repeated responding without consideration of the stimuli or task requirements (Perseverations). Accuracy dependent variables included: the failure to respond to target (non-X) letters (Omission Error); the response to non-target (X) letters (Commission Error); the discriminative power to differentiate between the signal (non-X) and noise (X) distributions (Detectability, d'); and the response tendency to be overly or less concerned about mistakenly responding to non-targets (Response Style, B). High T-scores (i.e., ≥ 60) indicated poor performance for all measures. However, high and low scores for B and Hit RT were considered noteworthy. The CCPT also generated a Confidence Index (CI) score (based on a discriminant function analysis) that provided an overall indication of whether the profile obtained for a respondent best fit a clinical or nonclinical profile (*n* = 174 individuals with ADHD between the ages of 6 and 11 in the standardization sample). Confidence Index values below 40 or above 60 were purported to offer evidence for nonclinical or clinical classification, respectively (Conners & MHS Staff, 2002).

Research Administrators

The primary investigator trained three doctoral-level graduate students and one advanced undergraduate student on the above tasks, using a combination of individual didactic and in-vivo (non-participant) training sessions. Together, the primary investigator and these four individuals individually conducted test sessions. Researchers were not blind to participants' diagnostic group membership.

Procedure

Prior to participation in the computer session, parents/guardians (preferably maternal) completed a screening packet containing an informed consent form, a demographic questionnaire, and the CPRS. Children (via parents/guardians) meeting study criteria were contacted and scheduled to complete a computer session.

The visual search task was administered first, with the flicker task and CCPT administered second and in counterbalanced order during a 75-min computer session. Of note, data collection for the current study was counterbalanced with data collection for a separate study. Participants sat comfortably without head restraint approximately 50 cm from the monitor. Testing occurred in a well-lighted room free of distraction; white noise was used to attenuate external sound. A researcher remained in the room during the computer session, due to flicker task requirements and, thus, for experimental control. For children currently taking medication for ADHD, parents/guardians consented to have their child abstain from ingesting those medications on the day of their computer session, and verbally confirmed adherence to this procedure at the time of testing.

For the visual search task, participants read on-screen instructions (Appendix B) to find a vertical blue bar (with a picture of the target presented on screen). Participants were instructed to press the “Y” or “N” key when they determined the target to be present or absent, respectively. For the flicker task, participants read on-screen instructions (Appendix C) that a change may occur to an image and that the change type would consist of appear/disappear (language that is more child-appropriate than “presence/absence”), color, or location. Participants were instructed to press the spacebar key when they detected the change, and then to report the change. For the CCPT, participants read on-screen instructions (Appendix D) to press the spacebar for every letter presented except the letter X. Prior to each task administration, participants paraphrased the instructions (to ensure understanding of the task) and completed the respective practice administrations.

Parents/guardians did not receive compensation for completing the screening packet. However, the families of children who met criteria for and participated in the computer phase received $50. In addition, children who participated in the computer phase received gift certificates for free ice cream, pizza, movie passes, roller-skating, and/or bowling.

RESULTS

Identification of a Covariate for Flicker Task Analyses

To identify a VST age-related performance variable to serve as a suitable covariate in flicker task analyses, a 2 (diagnostic group: ADHD, control) x 3 (age group: 6-8, 9-10, 11-12 years) x 2 (target presence: target-present, target-absent trials) x 3 (search type: color, orientation, conjunction) x 3 (array size: 4, 16, 36 items) mixed-design ANOVA was conducted for mean RT (correct trials only). Prior to running analyses, mean RT was calculated for each search condition, and outlier responses were recoded as the number of cycles immediately below three standard deviations above the mean of the respective search condition. Outlier rates were low, 0.64% across all data points, and did not differ between diagnostic group. Consistent with the visual search literature (Lobaugh et al., 1998), analyses yielded significant within-subjects main effects for target presence, $F(1, 53) = 50.10$, $p < .001$; search type, $F(2, 52) = 70.83$, $p < .001$; and array size, $F(2, 52) = 113.73$, $p < .001$. These significant main effects reflect that RT increased from target-present to target-absent trials, across search type (in the order of color feature, orientation feature, and conjunction), and across array size (in the order of 4, 16, and 36 items). In addition, and consistent with the visual search literature (Lobaugh et al., 1998), there was a significant interaction effect between target presence, search type, and array size, $F(4, 50) = 4.76$, $p < .01$. The conceptual significance and complexity of this interaction are beyond the scope of the current paper, but will be explicated in a future paper related directly to the visual search literature. Moreover, the within-subjects main and interaction effects are not discussed further due to the current focus on between-group findings (in the service of identifying a flicker task covariate).

Regarding between-group effects, there was a significant main effect of age group, $F(2, 53) = 19.66$, $p < .001$. Consistent with the visual search literature, age groups had been divided a priori into age ranges of 6 to 8, 9 to 10, and 11 to 12 years. Pairwise comparisons (hereafter Tukey) revealed that the youngest age group (6-8 years) displayed a significantly slower mean RT ($M = 2.02$ s, $SD = 0.38$) than the two older age groups (9-10 years: $M = 1.45$ s, $SD = 0.40$; 11-12 years: $M = 1.37$ s, $SD = 0.38$). There were no other significant main or interaction effects. To evaluate if VST mean RT would serve as a suitable covariate, the variable was entered as a covariate into preliminary flicker task analyses. It was determined that VST mean RT did not qualify as an appropriate covariate due to violating two assumptions regarding covariates (Field, 2009). First, covariates are expected to correlate well with intended dependent variables, which VST mean RT did not (i.e., very few significant correlations with flicker task dependent variables, and all below $r = .30$). Second, covariates are expected not to interact with independent variables, in that flicker task MANOVAs yielded significant interactions between VST mean RT and independent variables (e.g., degree of interest). Although VST mean RT was excluded as a covariate, it was directly related to age group. Therefore, age group was identified to serve as an additional independent variable for flicker task analyses (described below).

Between-Group and Within-Subjects Differences

Flicker Task. Prior to running analyses, the mean number of cycles was calculated for each flicker task item-pair, and outlier responses were recoded as the number of cycles immediately below three standard deviations above the mean of the respective item-pair. Outlier rates were low, 3.08% across all item-pairs, and did not differ between diagnostic groups.

To examine flicker task performance (Table 2), a 2 (diagnostic group: ADHD, control) x 3 (age group: 6-8, 9-10, 11-12 years) x 2 (degree of interest: central, marginal) x 3 (change type: color, presence/absence, location) mixed-design ANOVA was conducted for mean number of cycles needed to detect change. Regarding within-subjects

Table 2. Group Performance on Flicker Task Measures

	ADHD Group (*n* = 33)		Control Group (*n* = 28)	
Measure	*M*	*(SD)*	*M*	*(SD)*
Mean number of cycles				
Degree of interest				
Central	7.07	(2.70)	7.51	(3.53)
Marginal	13.62	(5.21)	20.27	(8.87)
Change type				
Color	8.98	(3.45)	10.83	(4.41)
Presence/absence	10.95	(4.55)	13.90	(7.90)
Location	10.22	(4.08)	14.91	(9.21)
Variability of mean number of cycles				
Degree of interest				
Central	6.93	(4.77)	8.21	(5.84)
Marginal	11.19	(6.38)	21.17	(14.32)
Change type				
Color	8.20	(4.80)	11.17	(7.80)
Presence/absence	10.35	(7.70)	17.54	(15.63)
Location	9.84	(6.21)	17.75	(12.34)

Note: ADHD = Attention-Deficit/Hyperactivity Disorder.

effects, there was a significant main effect of degree of interest, $F(1, 52) = 143.15$, $p < .001$, consistent with results from and using the same stimuli as Rensink et al. (1997) and Cohen and Shapiro (2007). Participants more rapidly detected central than marginal changes ($M = 7.13$ cycles [4.56 s], $SD = 2.32$; $M = 17.50$ cycles [11.2 s], $SD = 5.39$, respectively). There was also a significant main effect of change type, $F(2, 104) = 7.33$, $p < .001$. Pairwise comparisons revealed that mean number of cycles differed for each change type ($p < .02$), with participants needing fewer cycles to detect changes of color ($M = 10.21$ [6.53 s], $SD = 3.84$) than of presence/absence and location ($M = 12.89$ [8.25 s], $SD = 7.11$; $M = 13.85$ [8.86 s], $SD = 8.03$, respectively). However, there was a significant interaction between degree of interest and change type, $F(2, 104) = 10.08$, $p < .001$ (Figure 3). Comparison of cell means did not yield a significant difference for detecting central interest changes across change type, $F(2, 59) = 0.69$, $p > .05$), such that participants required a comparable number of cycles to detect changes of color, presence/absence, and location ($M = 7.40$ [4.74 s], $SD = 3.79$; $M = 7.31$ [4.68 s], $SD = 3.84$; $M = 6.70$ [4.29 s], $SD = 5.10$, respectively). In contrast, comparison of cell means indicated a significant difference for detecting marginal interest changes across change type, $F(2, 56) = 14.13$, $p < .001$), with participants needing fewer cycles to detect changes of color ($M = 13.02$ [8.33 s], $SD = 5.51$) compared to changes of presence/absence and location ($M = 18.47$ [11.82 s], $SD = 12.74$; $M = 21.00$ [13.44 s], $SD = 13.72$, respectively).

Figure 3. Flicker task mean number of cycles needed to detect change plotted by change type and degree of interest. Change type interacted with degree of interest.

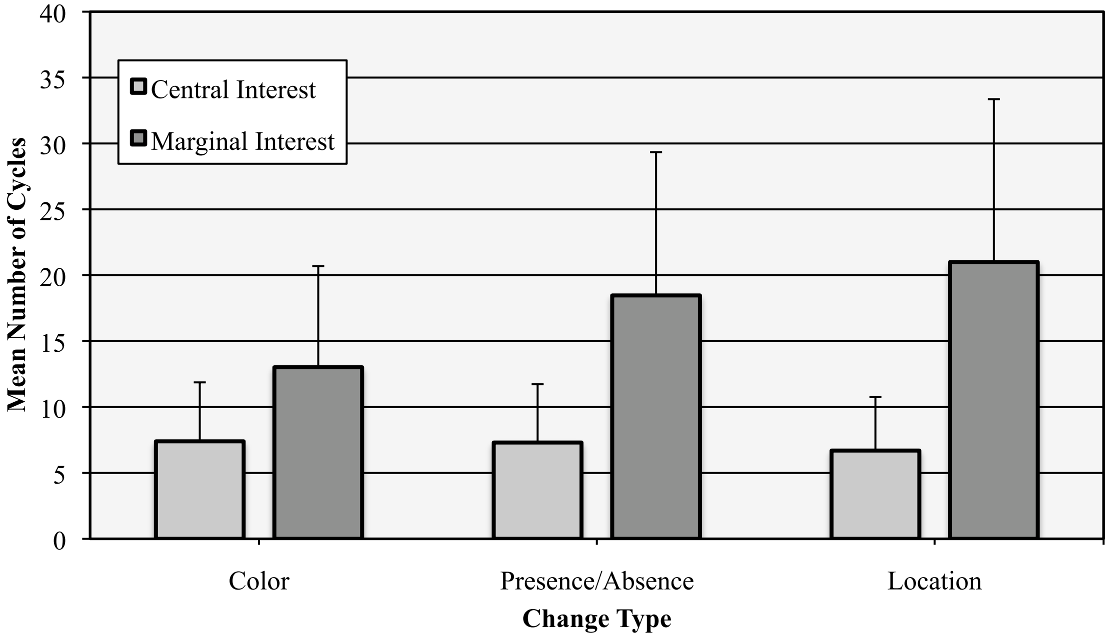
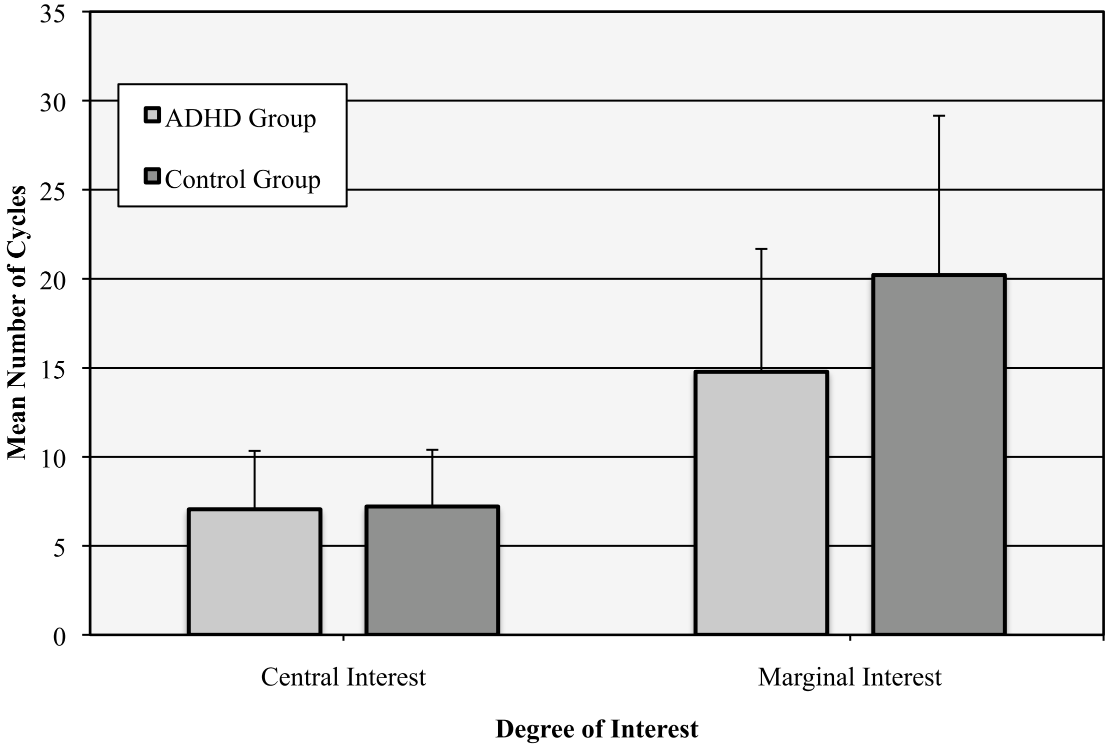


Figure 4. Flicker task mean number of cycles needed to detect change plotted by degree of interest and diagnostic group. Degree of interest interacted with diagnostic group.



Regarding between-group effects for the mean number of cycles needed to detect change, there was a significant main effect of age group, *F*(2, 52) = 3.65, *p* < .05, such that the youngest age group (6-8 years) displayed slower mean RTs (*M* = 14.52 cycles [9.29 s], *SD* = 4.75) compared to the two older age groups (9-10 years: *M* = 11.58 cycles [7.41 s], *SD* = 4.84; 11-12 years: *M* = 10.85 cycles [6.94 s], *SD* = 4.73). Also, there was a significant main effect of diagnostic group, *F*(2, 52) = 4.61, *p* < .05, in that the ADHD group displayed faster mean RTs than the control group (*M* = 10.92 cycles [6.99 s], *SD* = 4.77; *M* = 13.71 cycles [8.77 s], *SD* = 5.10, respectively). However, there was a significant mixed interaction between degree of interest (within-subjects) and diagnostic group (between-groups), *F*(1, 52) = 9.21, *p* < .01 (Figure 4). Comparison of cell means did not yield a significant difference for detecting central interest changes across diagnostic group (*p* > .05), such that both diagnostic groups required a comparable number of cycles to detect central interest changes (ADHD: *M* = 7.05 [4.51 s], *SD* = 3.12; Control: *M* = 7.21[4.61 s], *SD* = 3.45). In contrast, comparison of cell means indicated a significant difference for detecting marginal interest changes across diagnostic group (*p* < .001), in that the ADHD group needed fewer cycles (*M* = 14.78 [9.46 s], *SD* = 7.23) than the Control Group (*M* = 20.21 [12.93 s], *SD* = 8.00) to detect marginal interest changes. There were no other significant main or interaction effects.

Also with respect to flicker task performance (Table 2), a 2 (diagnostic group: ADHD, control) x 3 (age group: 6-8, 9-10, 11-12 years) x 2 (degree of interest: central, marginal) x 3 (change type: color, presence/absence, location) mixed-design ANOVA was conducted for variability of cycles involved in detecting change. Regarding within-subjects effects, there was a significant main effect of degree of interest, *F*(1, 48) = 48.33, *p* < .001, consistent with results from and using the same stimuli as Cohen and Shapiro

(2007). Participants exhibited greater variability for marginal than central changes (*M* = 14.36 cycles [9.19 s], *SD* = 10.25; *M* = 6.25 cycles [4.00 s], *SD* = 4.76; respectively). Although there was not a significant main effect of change type, there was a significant interaction between degree of interest and change type, *F*(2, 47) = 8.01, *p* < .001 (Figure 5). For central interest changes, comparison of cell means revealed that variability decreased across change type in the order of color, presence/absence, and location: changes in color involved significantly more variability than location changes (*M* = 7.82 cycles [5.00 s], *SD* = 6.83; *M* = 4.46 cycles [2.85 s], *SD* = 6.26, respectively), with presence/absence changes (*M* = 6.13 cycles [3.92 s], *SD* = 6.99) falling in between and showing no difference in variability among color and location changes. In contrast, for marginal interest changes, comparison of cell means revealed that variability increased across change type in the order of color, presence/absence, and location: changes in color involved significantly less variability than location changes (*M* = 10.25 cycles [6.56 s], *SD* = 9.27; *M* = 17.23 cycles [11.03 s], *SD* = 15.14, respectively), with presence/absence changes (*M* = 15.61 cycles [9.99 s], *SD* = 19.70) falling in between and showing no difference in variability among color and location changes.

Regarding between-group effects for variability of cycles involved in detecting change, there was a significant main effect of diagnostic group, *F*(1, 48) = 4.35, *p* < .05, in that the ADHD group displayed significantly less variability in RT than the control group (*M* = 8.49 cycles [5.43 s], *SD* = 6.26; *M* = 12.12 cycles [7.76 s], *SD* = 6.56, respectively). However, there was a significant mixed interaction between degree of interest (within-subjects) and diagnostic group (between-groups), *F*(1, 48) = 5.74, *p* < .05. (Figure 6). For central interest changes, comparison of cell means did not yield a significant difference in variability across diagnostic group (*p* > .05), such that both

Figure 5. Flicker task variability of mean number of cycles involved in detecting change plotted by change type and degree of interest. Change type interacted with degree of interest.

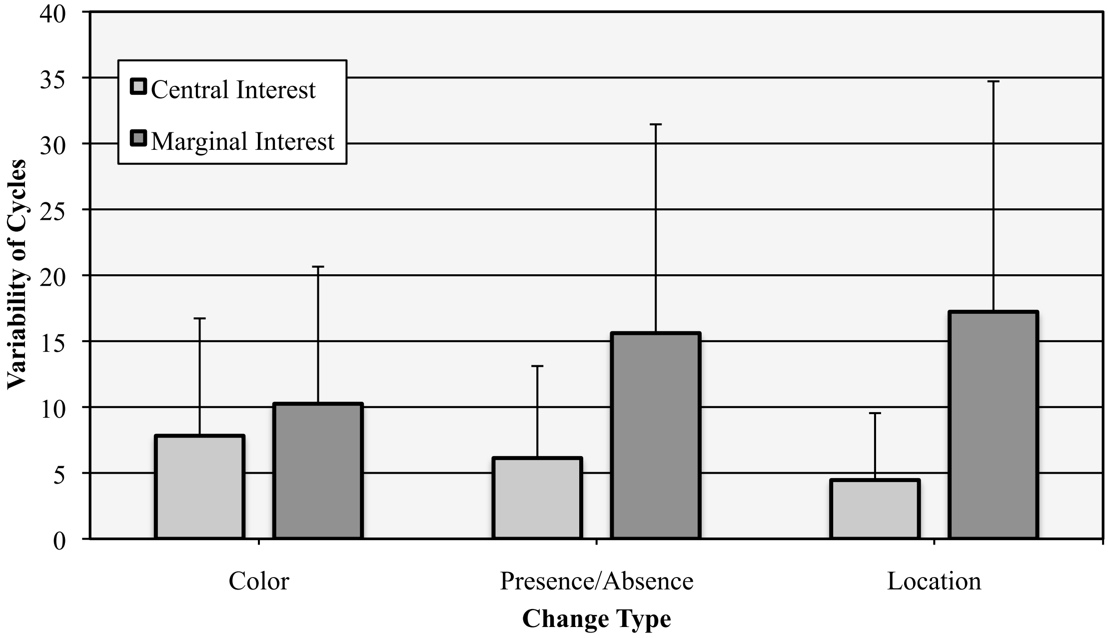
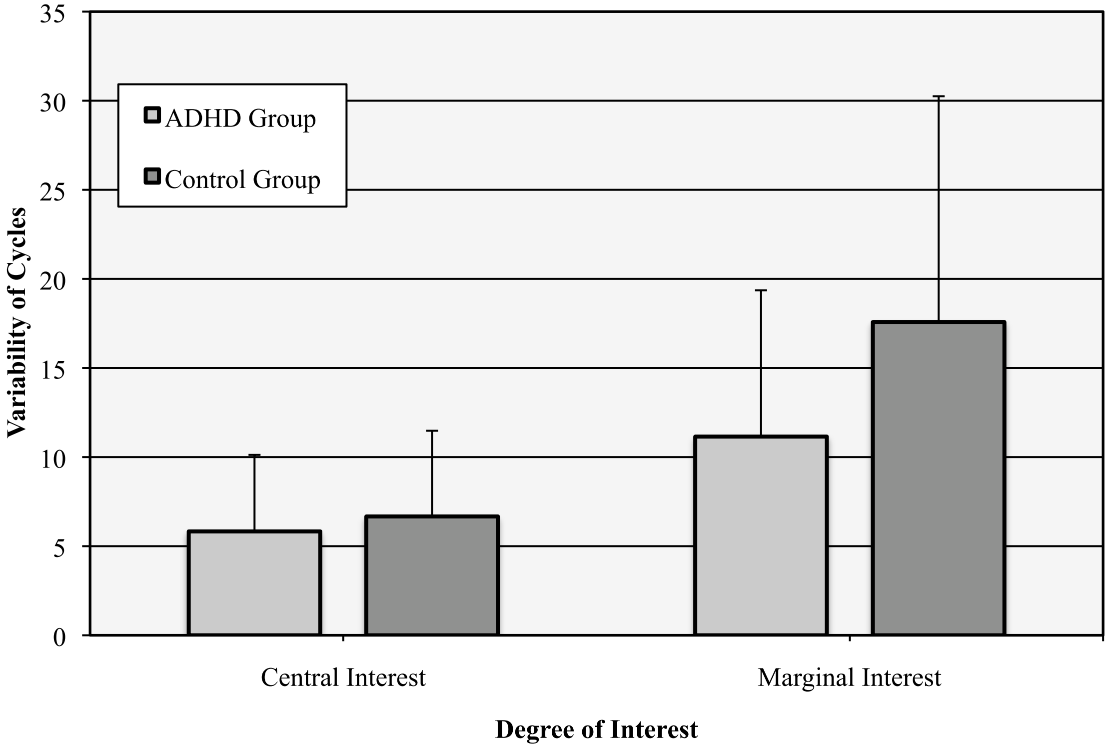


Figure 6. Flicker task variability of mean number of cycles involved in detecting change plotted by degree of interest and diagnostic group. Degree of interest interacted with diagnostic group.



diagnostic groups showed comparable variability in detecting central interest changes (ADHD: *M* = 5.83 [3.73 s], *SD* = 4.48; Control: *M* = 6.67 [4.27 s], *SD* = 4.70). In contrast, for marginal interest changes, comparison of cell means indicated a significant difference in variability across diagnostic group, in that the ADHD group showed less variability than the control group in detecting marginal interest changes (*M* = 11.15 [7.14 s], *SD* = 9.65; *M* = 17.58 [11.25 s], *SD* = 10.13, respectively). There were no other significant main or interaction effects.

To examine flicker task performance over time, a 2 (diagnostic group: ADHD, control) x 3 (age group: 6-8, 9-10, 11-12 years) x 6 (time block) mixed-design ANOVA was conducted separately for mean number of cycles and variability of cycles needed to detect change. For mean number of cycles needed to detect change over time, there was a significant main effect of diagnostic group, $F(1, 53) = 4.37$, $p < .05$, whereby the ADHD group required fewer cycles to detect change than the control group. This significant effect reflects results reported above, specifically that the ADHD group needed fewer cycles than the control group to detect marginal interest changes. There were no other significant main or interaction effects, such that the mean number of cycles (Figure 7) needed to detect change over time did not differ by diagnostic group or by time block. Further analyses were not conducted regarding mean number of cycles, although a visual representation is provided for mean number of cycles over two time blocks (Figure 8).

Figure 7. Flicker task mean number of cycles needed to detect change plotted by time block (6). Mean number of cycles did not change over time.

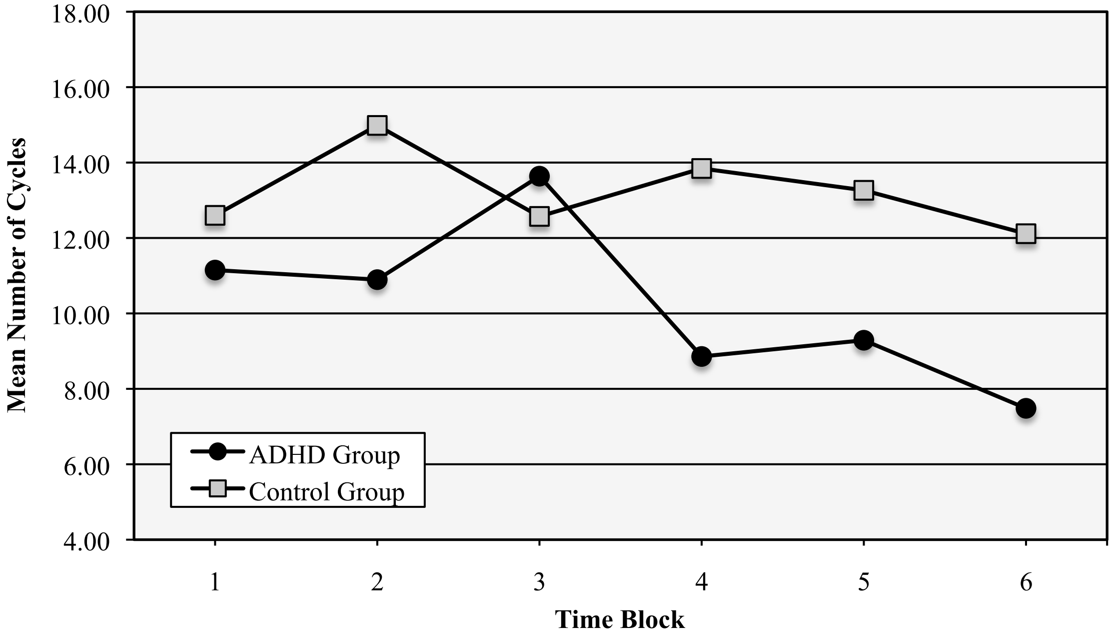
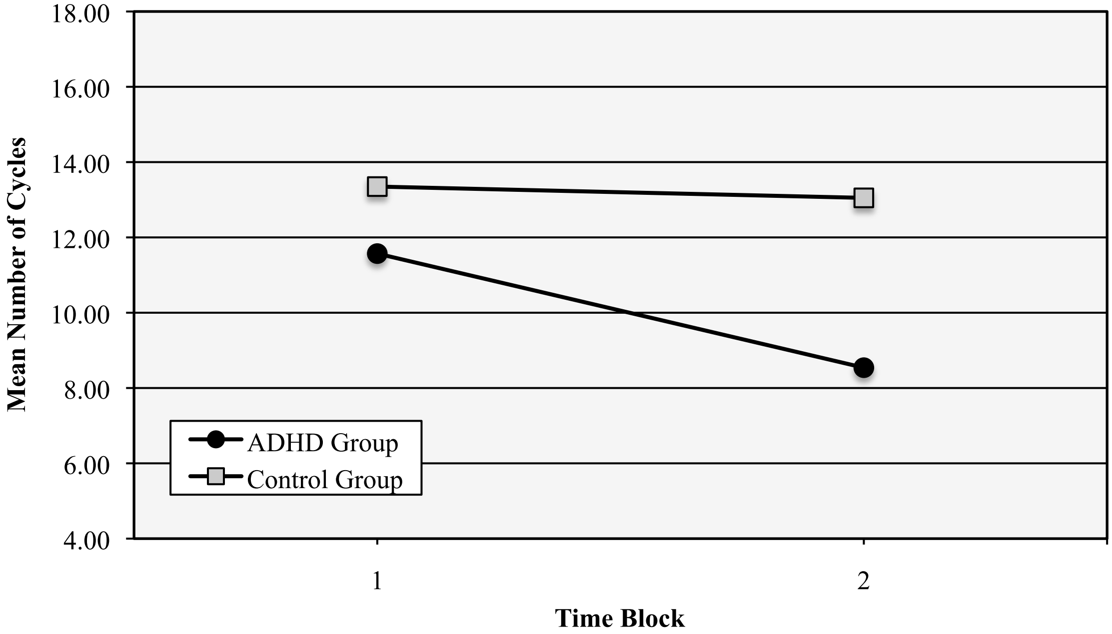


Figure 8. Flicker task mean number of cycles needed to detect change plotted by time block (2). Mean number of cycles did not change over time.



Regarding variability of cycles needed to detect change over time, there was a main effect of time block, *F*(5, 47) = 2.47, *p* < .05 (Figure 9), such that variability of cycles needed to detect change varied across the six time blocks. A secondary ANOVA was conducted, using two instead of six time blocks, to gain a more direct understanding of how variability of cycles changed over time. That is, a 2 (diagnostic group: ADHD, control) x 3 (age group: 6-8, 9-10, 11-12 years) x 2 (time block) mixed-design ANOVA was conducted, yielding a main effect for variability of cycles over time, *F*(1, 55) = 4.75, *p* < .05 (Figure 10). Participants showed greater variability of cycles in the first half compared to the second half of the flicker task. Also, in both the primary (6 time blocks) and secondary (2 time blocks) ANOVAs used to examine variability of cycles, there was a significant main effect of diagnostic group, *F*(1, 51) = 8.05, *p* < .01 (primary ANOVA), *F*(1, 55) = 10.25, *p* < .01 (secondary ANOVA), whereby the ADHD group showed less variability of cycles needed to detect change than the control group. This significant effect also reflects results reported above, specifically that the ADHD group showed less variability than the control group in detecting marginal interest changes. There were no other significant main or interaction effects.

To examine accuracy, a 2 (diagnostic group: ADHD, control) x 3 (age group: 6-8, 9-10, 11-12 years) mixed-design ANOVA was conducted separately for commission and omission errors. For commission errors, there was a significant main effect of age group, *F*(1, 55) = 4.61, *p* < .05 (Figure 11). Pairwise comparisons revealed that the youngest age group (6-8 years: (*M* = 10.08, *SD* = 8.53) made significantly more commission errors than the oldest age group (11-12 years: *M* = 4.23, *SD* = 4.58), with the middle age group

Figure 9. Flicker task variability of mean number of cycles involved in detecting change plotted by time block (6). Mean number of cycles changed over time.

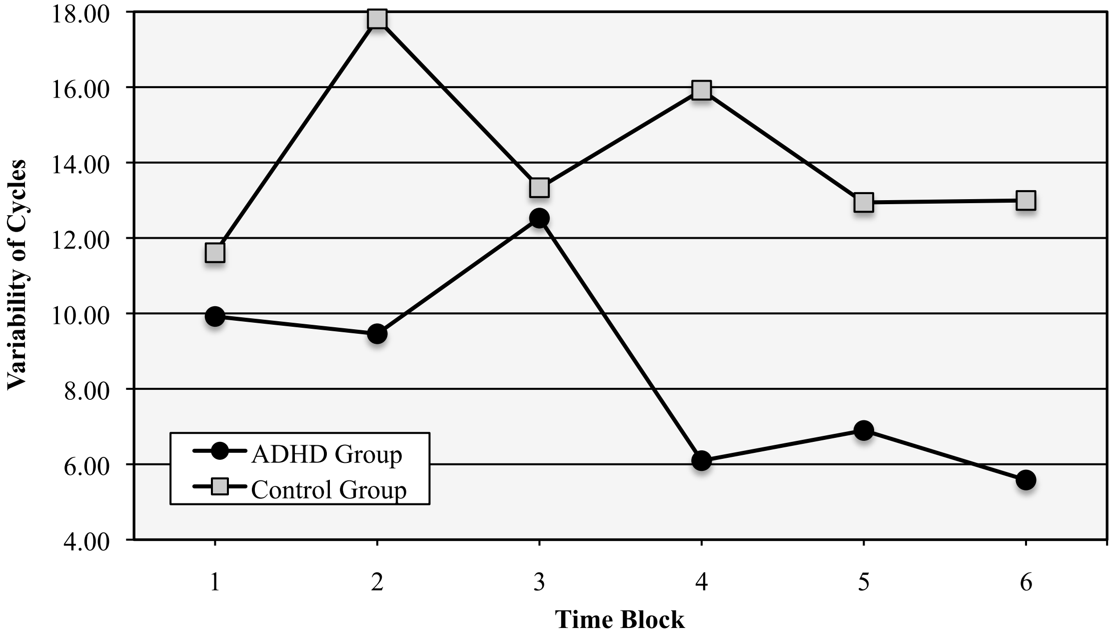
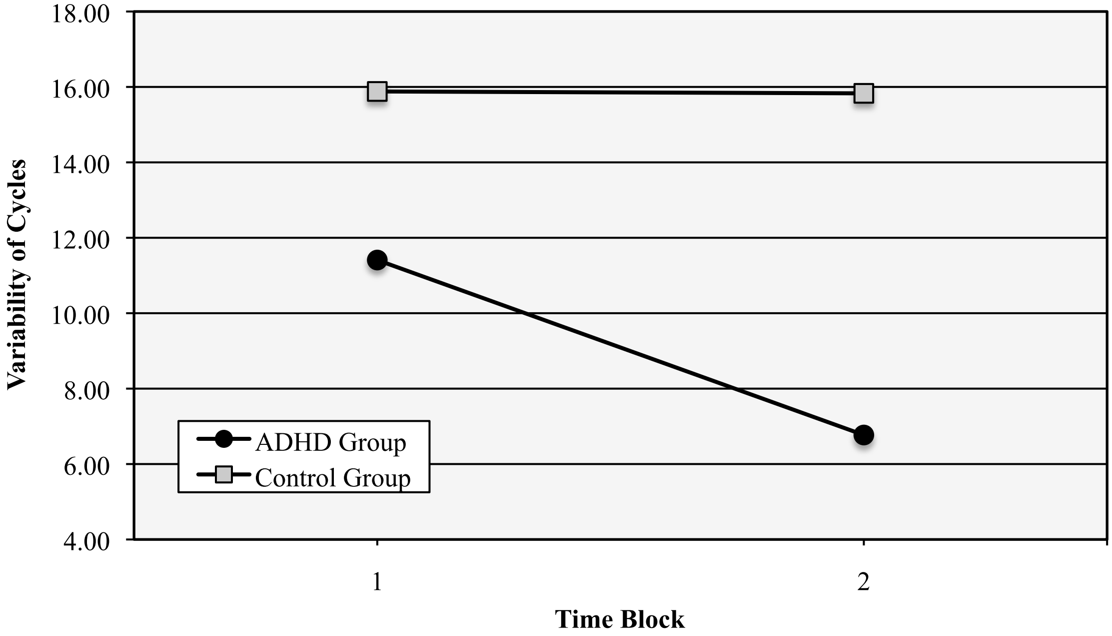


Figure 10. Flicker task variability of mean number of cycles involved in detecting change plotted by time block (2). Mean number of cycles changed over time.



(9-10 years: *M* = 6.69, *SD* = 6.95) falling in between and showing no difference in commission errors among the youngest and oldest groups. Also, there was a marginal main effect of diagnostic group, *F*(1, 55) = 3.83, *p* = .055 (Figure 12), such that the

Figure 11. Flicker task commission and omission errors plotted by age group. Commission errors interacted with age group, whereas omission errors did not.

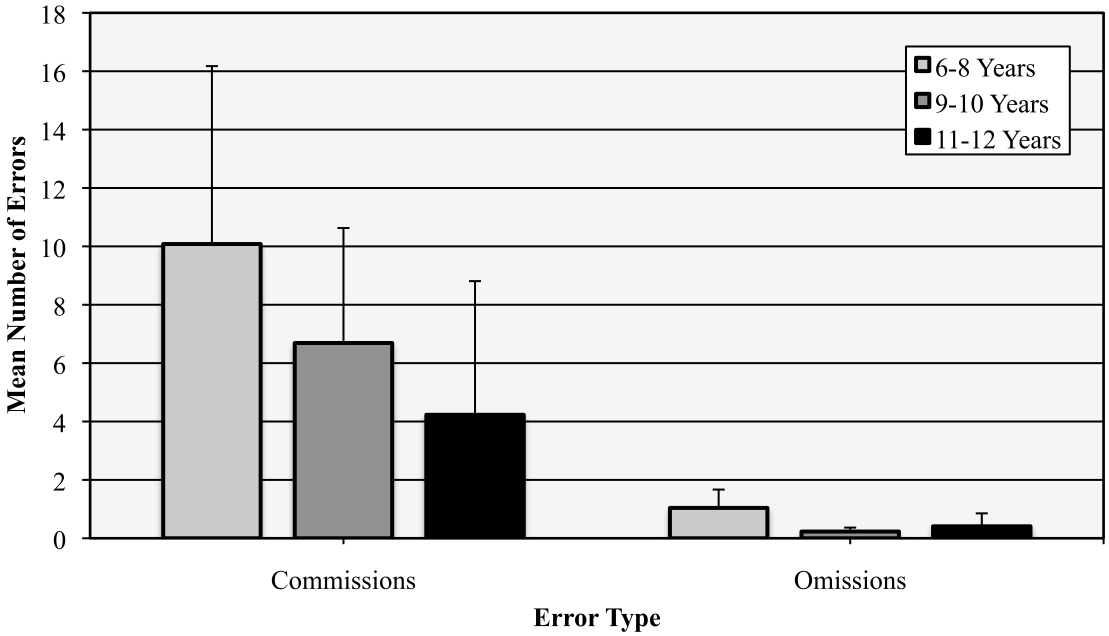
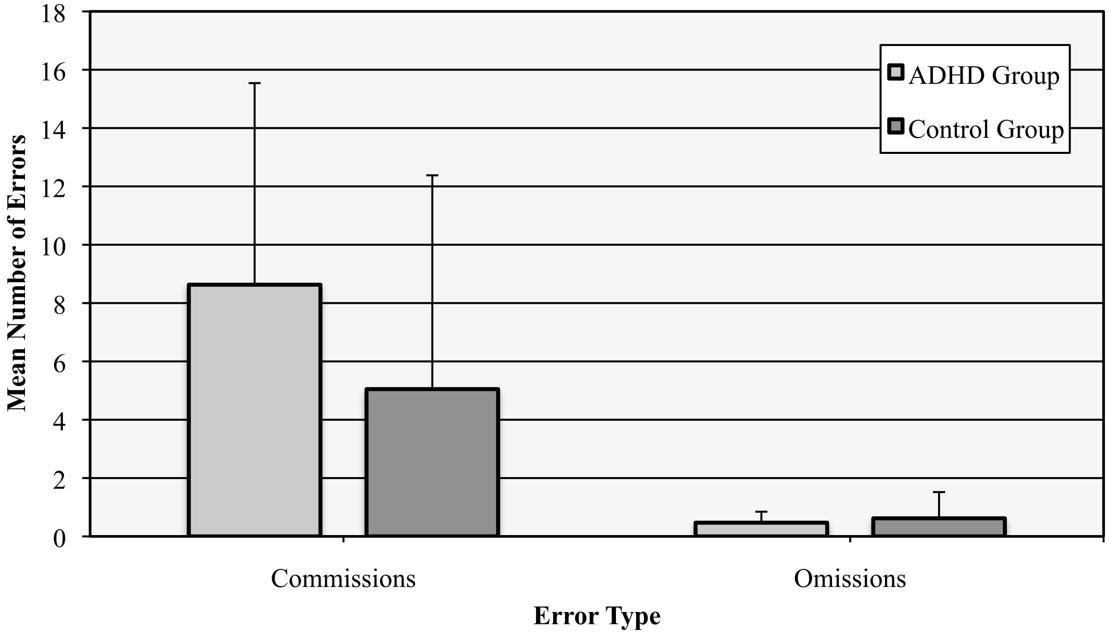


Figure 12. Flicker task commission and omission errors plotted by diagnostic group. Commission errors interacted with diagnostic group, whereas omission errors did not.



ADHD group (*M* = 8.64, *SD* = 6.92) made marginally more commission errors than the control group (*M* = 5.05, *SD* = 7.33). There was no significant interaction effect between diagnostic and age group. Regarding omission errors, there were no main or interaction effects (Figures 11 & 12; ADHD: *M* = 0.47, *SD* = 1.44; Controls: *M* = 0.62, *SD* = 1.53).

To examine accuracy over time, 2 (diagnostic group: ADHD, control) x 3 (age group: 6-8, 9-10, 11-12 years) x 6 (time block) mixed-design ANOVAs were conducted separately for commission and omission errors. There was no significant main or interaction effect of time block for commission or omission errors.

CCPT. T-scores for all dependent variables are presented in Table 3. A MANOVA was conducted to test mean differences between the ADHD and control group

Table 3. Group Performance on CCPT Variables

	ADHD Group (*n* = 33)		Control Group (*n* = 28)	
Measure	*M*	*(SD)*	*M*	*(SD)*
Reaction time				
Hit RT	56.26	(12.21)	49.91	(11.71)
Variability				
Hit RT SE	58.95	(10.71)	50.58	(7.90)
Variability	57.56	(10.53)	50.08	(9.77)
Hit RT block change	56.16	(12.94)	50.96	(11.22)
Hit SE block change	53.48	(7.41)	50.59	(10.95)
Hit RT ISI change	58.85	(16.18)	52.43	(8.43)
Hit SE ISI change	54.18	(10.75)	51.02	(9.77)
Perseverations	69.59	(33.33)	53.11	(20.45)
Accuracy				
Omission errors	59.79	(21.41)	48.38	(8.75)
Commission errors	49.07	(11.39)	46.23	(12.74)
Detectability (d')	52.54	(12.41)	47.07	(14.10)
Response style (B)	57.13	(14.48)	52.72	(13.80)
Overall profile (clinical vs. non-clinical)				
Confidence index	66.45	(21.44)	50.73	(15.19)

Note. ADHD = Attention-Deficit/Hyperactivity Disorder; RT = reaction time; SE = standard error; ISI = interstimulus interval. All scores except Confidence Index (raw) refer to T-scores.

for the CCPT dependent variables (age group was not included as a covariate due to the fact that CCPT *T*-scores are age-adjusted). The MANOVA failed to yield a significant main effect of diagnostic group, $F(13, 47) = 1.10$, $p > .05$, although univariate tests yielded significant group differences for seven variables. An exploration of the CCPT data indicated two violations of MANOVA assumptions (Field, 2009)—(1) an elevated number of outliers and (2) a considerable degree of high correlations among CCPT variables (see Table 4)—which likely contributed to decreased power to obtain a significant main effect. To address the CCPT outliers, mean T-scores were calculated for each CCPT dependent variable, and outlier results were recoded as the T-score corresponding to three standard deviations above the mean of the respective dependent

Table 4. Pearson Correlations Among CCPT Dependent Variables

Dependent Variable	CI	1	2	3	4	5	6	7	8	9	10	11	12
CI	1.000	.840**	.107	.425**	.871**	.771**	.262*	.299*	.584**	.539**	.415**	.549**	.433**
1. Omissions		1.000	.235	.250	.771**	.736**	.397**	.241	.528**	.415**	.287*	.425**	.466**
2. Commissions			1.000	-.561**	.161	.329**	.854**	-.021	.400**	.068	.234	.043	.219
3. Hit RT				1.000	.530**	.223	-.377**	.310*	.113	.318*	.032	.455**	.159
4. Hit RT SE					1.000	.910**	.229	.280*	.675**	.543**	.435**	.650**	.604**
5. Variability						1.000	.338**	.204	.639**	.474**	.507**	.533**	.718**
6. Detectability (d’)							1.000	.171	.294*	.175	.204	.104	.225
7. Response Style (B)								1.000	.097	.158	.057	.195	.115
8. Perseverations									1.000	.168	.189	.503**	.322*
9. Hit RT Block Change										1.000	.688**	.451**	.322*
10. Hit SE Block Change											1.000	.321*	.408**
11. Hit RT ISI Change												1.000	.600**
12. Hit SE ISI Change													1.000

Note. n = 61. CCPT = Conners’ Continuous Performance Test; CI = Confidence Index; RT = reaction time; SE = standard error; ISI = interstimulus interval; all scores except Confidence Index (raw) refer to T-scores.
*p < .05. **p < .01

variable. Outlier rates differed between diagnostic group ($p < .05$), with a higher rate of outliers for children with ADHD (5.59%) than without ADHD (1.10%). To address the high correlations among CCPT variables, the number of highly correlated variables to be included in the MANOVA was reduced by selecting variables that (1) shared the fewest number of reasonably strong correlations (i.e., less than .5), (2) are commonly examined in the research literature (Epstein et al., 1998, 2003), and (3) represented the three domains of CCPT dependent variables (i.e., RT, variability, accuracy).

A secondary MANOVA was conducted to test mean differences between the ADHD and control group for the CCPT dependent variables, thus including the variables of Hit RT (reaction time), Hit RT SE and Detectability (d'; variability), and Omission and Commission Errors (accuracy). There was a significant main effect of diagnostic group, $F(5, 55) = 2.65, p < .05$. Examination of the CCPT results showed that the T-scores for all dependent variables included in the secondary MANOVA were in the non-clinical range (see Table 3). Participants with ADHD had slower reaction mean, $F(1, 59) = 4.26$, $p < .05$ and greater variability of mean RT, $F(1, 59) = 11.64, p < .001$. Also, participants with ADHD had higher omission error rates than did controls, $F(1, 59) = 7.51, p < .01$.

A standalone independent-samples *t* test was conducted to test the mean difference between diagnostic groups for the CCPT variable of Confidence Index (CI) score. The rationale for conducting this individual comparison stemmed from the CI score being a composite variable (based on discriminant function analysis) intended to provide an overall indication of whether the respondent's performance best fits a clinical or nonclinical profile. There was a significant main effect of CI score, $t(59) = 3.25, p <$

.01, such that the ADHD group obtained scores suggesting a clinical profile (i.e., ≥ 60T; *M* = 66.45, *SD* = 21.44) compared to control group scores suggesting a nonclinical profile (i.e., < 60T; *M* = 50.73, *SD* = 15.19).

Correlations Between Flicker Task and CCPT Dependent Variables and CPRS Scores

Bivariate correlations between flicker task and CCPT dependent variables and CPRS scores were examined to determine if any dependent variable was differentially associated with inattention, hyperactivity/impulsivity, or total ADHD symptoms (Table 5). Regarding the flicker task, (a) mean number and variability of cycles for marginal

Table 5. Pearson Correlations Between Flicker Task and CCPT Dependent Variables and ADHD Symptomatology

	DSM-IV Inattentive sx	DSM-IV Hyperactive/impulsivity sx	DSM-IV ADHD sx total
Flicker task			
Marginal interest changes			
Mean number of cycles	-.334**	-.422**	-.392**
Variability of cycles	-.334**	-.380**	-.366*
Change of location			
Mean number of cycles	-.246	-.320*	-.294*
Variability of cycles	-.384**	-.294*	-.371**
2nd half administration			
Mean number of cycles	-.247	-.304*	-.292*
Variability of cycles	-.348**	-.381**	-.386**
Commission errors			
Overall	.274*	.274*	.269*
1st half administration	.304*	.310*	.302*
CCPT			
Confidence index	.317*	.303*	.321*
HIT RT	.267*	.297*	.273*
HIT RT SE	.361**	.363**	.376**
Omission errors	.311*	.287*	.310*
Variability	.293*	.277*	.297*

Note. n = 61. CCPT = Conners' Continuous Performance Test; ADHD = Attention-Deficit/Hyperactivity Disorder; DSM = *Diagnostic and Statistical Manual of Mental Disorders* (4th ed., text revision); sx = symptoms; RT = reaction time; SE = standard error; flicker task scores refer to raw scores. CCPT scores refer to T-scores.

interest changes, (b) mean number and variability of cycles for the second half of the flicker task administration, and (c) mean number and variability of cycles for changes in location were significantly correlated (for virtually all of these variables) with inattention, hyperactivity/impulsivity, and total ADHD symptoms. Surprisingly, these results indicate that faster RT with less variability needed to detect change for the most difficult degree (i.e., marginal interest) and type (i.e., location) of changes reflected elevated ADHD symptomatology. In addition, (d) mean commission errors and (e) commission errors occurring in the first half of the administration were significantly correlated with inattention, hyperactivity/impulsivity, and total ADHD symptoms, suggesting that increased commission errors (including increased early errors) reflected elevated ADHD symptomatology. A few other correlations between flicker task and CPRS scores were significant, but did not provide further interpretive clarity and therefore are not presented here.

Regarding the CCPT, Confidence Index, omission errors, HIT RT, HIT RT SE, and variability were significantly correlated with inattention, hyperactivity/impulsivity, and total ADHD symptoms, suggesting that the increased tendency for a clinical profile (based on the CCPT's discriminant function analysis), increased omission errors, increased mean RT, increased variability of mean RT, and increased "within-respondent" variability reflected elevated ADHD symptomatology. Correlations between parallel performance measures of the flicker task and CCPT were also examined to assess similarity of measured constructs (i.e., flicker task cycles/CCPT RT, variability, and accuracy). Within the domain of accuracy, three significant correlations emerged between

CCPT Omission Errors and flicker task commissions ($r = .36, p < .01$). No other correlations were significant for accuracy or within the domains of RT or variability (all ps > .05).

Discriminative Utility

Flicker Task. To examine the utility of the flicker task in differentiating individuals with and without ADHD, only dependent variables that demonstrated statistically significant between-group differences (mean number and variability of cycles for marginal interest changes) were entered (using T-scores) as predictors in a forward stepwise logistic regression. Inclusion of dependent variables was based on an alpha of .05. Variability of cycles for marginal interest changes remained in the final equation and was associated with a Beta weight of 0.09; an estimated odds ratio of 1.09; and a Wald value of 8.52, $p < .01$. The resulting classification matrix correctly identified 26 of 32 members of the ADHD group, producing a sensitivity coefficient of 81.3%; and 14 of 28 members of the control group, producing a specificity coefficient of 50.0%. The overall correct classification rate was 66.7%. Positive and negative predictive power was 65.0% and 70.0%, respectively.

CCPT. To examine the diagnostic utility of the CCPT, dependent variables that demonstrated statistically significant between-group differences (Hit RT, Hit RT SE, Commission Errors, Confidence Index) were entered (using T-scores) as predictors in a forward stepwise logistic regression. Inclusion of dependent variables was based on an alpha of .05. Only Hit RT SE remained in the final equation and was associated with a Beta weight of -.10; an estimated odds ratio of 0.91; and a Wald value of 8.50, $p < .01$.

The resulting classification matrix correctly identified 24 of 33 members of the ADHD group, producing a sensitivity coefficient of 72.7%; and 18 of 28 members of the Control group, producing a specificity coefficient of 64.3%. The overall correct classification rate was 68.9%. Positive and negative predictive power was 70.6% and 66.7%, respectively. Of note, additional exploratory logistic regression analyses were conducted using factorial combinations of the CCPT dependent variables, which yielded identical results to the above CCPT logistic regression.

Combined Tasks. The combined diagnostic utility of the flicker task and CCPT was examined. Dependent variables from the flicker task and CCPT that demonstrated statistically significant between-group differences (as noted above) were entered (using T-scores) as predictors in a forward stepwise logistic regression. Inclusion of dependent variables was based on an alpha of .05. Only the flicker task dependent variable of variability of cycles for marginal interest changes and the CCPT dependent variable of Hit RT SE remained in the final equation and were associated, respectively, with a Beta weight of 0.10 and -0.12; an estimated odds ratio of 1.11 and 0.883; and a Wald value of 9.80, $p < .01$, and 8.08, $p < .01$. The resulting classification matrix correctly identified 25 of 32 members of the ADHD group, producing a sensitivity coefficient of 78.1%; and 18 of 28 members of the Control group, producing a specificity coefficient of 64.3%. The overall correct classification rate was 71.7%. Positive and negative predictive power was 71.4% and 72.0%, respectively.

DISCUSSION

The CPT is a laboratory paradigm that is widely used to help diagnose ADHD. However, the diagnostic and discriminative utility of CPTs is generally poor. In the search for a more accurate measure for differentiating children with and without ADHD, Rensink et al.'s (1997) flicker task was considered. The flicker task is a computerized measure of attention used to demonstrate change blindness, the phenomenon whereby observers have difficulty detecting surprisingly large environmental changes in the presence of a competing change. Research has established the ecological validity of change blindness, such that change blindness has been demonstrated during a computerized flicker task (Rensink et al., 1997) as well as during a real-world occlusion event (Simons & Levin, 1998). The use of environmentally realistic stimuli in the flicker task (photographs of real-world scenes) was hypothesized to offer superior ecological validity than the CCPT stimuli (the presentation of letters). Compared to the relative simplicity of detecting target letters in the CCPT, the complexities of detecting change in the flicker task's real-world scenes was hypothesized to prove more challenging for children with than without ADHD, such that the flicker task was expected to differentiate more effectively children with and without ADHD compared to the CCPT. Thus, this study examined the ability of the flicker task to provide improved discriminative utility regarding ADHD than the CCPT, whereby flicker task and CCPT performance was compared between the ADHD and control group.

Discriminative Utility

Contrary to current prediction, the flicker task does not demonstrate better discriminative utility compared to the CCPT. Instead, results indicate that both the flicker task and CCPT provide insufficient discriminative utility. Current CCPT sensitivity (72.7%) and specificity (64.3%) appear to be superior and inferior, respectively, compared to past CCPT studies, with Epstein et al. (1998) reporting sensitivity and specificity of 55% and 76.4%, respectively, and McGee et al. (2000) reporting sensitivity of 52% (but not reporting specificity). Comparing adult and child CCPT discriminative utility from the same research group, current child CCPT sensitivity is similar while specificity is inferior, with Cohen and Shapiro (2007) reporting adult CCPT sensitivity and specificity of 71% and 77%, respectively. Consistent with results from Cohen and Shapiro (2007), the seeming improvement in CCPT sensitivity, but not specificity, may be due in part to the increased homogeneity of the sample compared to that used in the above two CCPT studies from independent research groups (Epstein et al., 1998; McGee et al., 2000). For example, Epstein et al.'s (1998) sample of adults with ADHD included a wide range of age and development (i.e., M = 35 years, SD = 11 years), and McGee et al.'s (2000) sample included an ADHD group that did not have an established ADHD diagnosis prior to the study. Increased sample homogeneity may have yielded an ADHD group with relatively uniform attentional difficulties, thereby enhancing the ability of the CCPT to detect abnormal performance from the ADHD group, that is, sensitivity. In contrast, it is unlikely that increased sample homogeneity would increase the uniformity of attention in the control group or enhance the ability of the CCPT to detect normal performance in a normal sample. Therefore, an improvement in specificity reported in prior studies would not be expected, especially given past CCPT studies have reported relatively high specificity. However, decreased specificity in the current study compared to past CCPT studies was unexpected, and plausible explanations related to characteristics of the current control sample are not readily apparent.

Current flicker task sensitivity (81.3%) and specificity (50%) are superior and inferior, respectively, to results from past CCPT studies as well as current CCPT results. Notably, the flicker task and CCPT both produced superior sensitivity compared to specificity, which starkly contrasts the overall finding in the literature that CPTs exhibit moderate specificity but weak sensitivity (Barkley, 2006; Epstein et al., 1998; Nichols & Waschbusch, 2004; Riccio et al., 2001). It is unclear why the flicker task and CCPT in the present study demonstrated improved ability to detect the presence of attentional and impulsive difficulties, but reduced ability to detect the absence thereof. These results, discrepant with prior research, highlight the need for continued study of CPTs in general, additional research on CPT performance in childhood, and continued examination of flicker task performance in children and adults. In addition, current overall correct classification for the flicker task and CCPT are similarly low (66.7% and 68.9%, respectively), which replicates findings from Cohen and Shapiro (2007; 72% and 74%, respectively). Consistent with prior research, sensitivity, specificity, and overall correct classification of these measures are insufficient to support their utility in discriminating children with and without ADHD.

It should be noted that studies (including the present research) examining the CCPT have used various methods to determine diagnostic status and discriminative and/or diagnostic utility, such as using logistic regression or discriminant function analysis, examining between-group differences, or establishing an arbitrary cut-off score for a given dependent variable to ascribe abnormal performance (Epstein et al., 1998; McGee et al., 2000; Solanto et al., 2004; Walker et al., 2000). Utilization of one method over another to determine diagnostic utility may serve to highlight the difference in goals regarding the understanding of ADHD. For example, researchers may use logistic regression to examine differences at the group level, whereas clinicians may use a criterion of 1.5 standard deviations above the mean to identify ADHD at the individual level. Also, researchers examining CCPT diagnostic utility have used "best-case" sensitivity and specificity analyses. That is, researchers have conducted analyses to determine sensitivity and specificity using only significant between-group dependent variables, which may yield enhanced diagnostic utility compared to diagnostic software that accompanies a commercially available CPT (Cohen & Shapiro, 2007; Epstein et al., 1998; Solanto et al., 2004). In general, the lack of uniformity in determining CCPT diagnostic utility suggests exercising caution when interpreting results.

Between-Group and Within-Subjects Differences

Although flicker task and CCPT provide similarly insufficient discriminative utility, further exploration of group performance provided additional information about the characteristics of these two measures.

CCPT. Consistent with current prediction and prior CCPT research in children (Epstein et al., 2003) and adults (Murphy et al., 2001; Walker et al., 2000), children with ADHD demonstrated worse accuracy (greater Omission Errors) and greater Variability (increased variability of RT) compared to controls. In addition, performance by the ADHD group produced an elevated Confidence Index compared to the control group. Various CCPT studies with children and adults with ADHD indicate that the CCPT Confidence Index offers minimal discriminative utility (Cohen & Shapiro, 2007; Edwards et al., 2007; McGee et al., 2000; Weis & Totten, 2004), making it relatively surprising that the current study produced a group difference for this variable. Conners and colleagues (2002) reported providing the Confidence Index as an overall indication of whether the profile obtained for a respondent best fits a clinical or nonclinical profile, but cautioned that results from one variable (or one test instrument) should not serve as a litmus test for ADHD.

Contrary to current prediction, there was no diagnostic group difference for commission errors. This result is moderately surprising, given that most child (Epstein et al., 2003; Shaw et al., 2005) and adult (Cohen & Shapiro, 2007, Epstein et al., 1998; Murphy et al., 2001; Walker et al., 2000) studies have found group differences for commission errors, although some studies in children (McGee et al., 2000) and adults (Solanto et al., 2004) have not. Also contrary to current prediction, the ADHD group demonstrated slower mean RT compared to controls. Many CCPT studies suggest that children and adults with and without ADHD do not differ in RT (Epstein et al., 1998, 2003; McGee et al., 2000; Murphy et al., 2001; Roy-Byrne et al., 1997; Solanto et al., 2004; Walker et al., 2000), although there exist various CPT findings in the literature that child and adults with ADHD do in fact show slower RT (Hervey et al., 2006). To investigate this discrepancy, Hervey et al. (2006) examined CCPT performance in children with and without ADHD by utilizing an innovative approach of modeling RT and variability of RT with an ex-Gaussian (non-normal) curve (compared to traditional studies that assumed a normal/Gaussian distribution). Briefly, the ex-Gaussian curve represents the combination of the independent Gaussian (normal) distribution and exponential random variables, with the latter constituting the positive skew of the distribution curve. The ex-Gaussian distribution has three parameters: μ (mu), the mean of the normal component; σ (sigma), the standard deviation of the normal component; and τ (tau), a value indicating more frequent excessively long RTs, represented as positive skew in the ex-Gaussian distribution. Greater tau is different than a general slowing of RT. Although a general slowing may indicate a variety of unspecified difficulties with basic cognitive processes, periodic excessively long RT has been argued to be a consequence of poor attention (Hervey et al., 2006). Consistent with traditional CPT studies that assumed a normal distribution, Hervey et al.'s (2006) data suggested that RTs for children with ADHD were slower and more variable than matched comparison youth. However, as noted above, this information assumed a normal distribution with equal RTs on either side of the mean. Instead, when separating RT into two separate theoretical distributions (i.e., normal and positively skewed), Hervey et. al (2006) found that children with ADHD were slower in their overall responses associated with the positively skewed portion of the ex-Gaussian curve (tau). That is, children with ADHD had a greater number of RTs that were well beyond their mean performance than the control group. Notably, children with ADHD demonstrated no overall difference in the standard deviation of the normal portion of the RT distribution curve (sigma).

Furthermore, children with ADHD demonstrated a significantly smaller mu compared to the control group, which indicates that children with ADHD demonstrated faster overall mean RT associated with the normally distributed portion of the ex-Gaussian distribution. Thus, at times, children with ADHD responded more quickly than controls. One explanation for such a result is that children with ADHD are impulsive responders (Hervey et al., 2006).

Flicker Task. The youngest age group (6-8 years) displayed slower mean RT compared to the two older age groups (9-10 and 11-12 years), an age effect that is consistent with the visual search literature (Lobaugh et al., 1998). This age effect did not influence flicker task results, as slower RT for the youngest group did not vary by diagnostic group.

Concerning within-subjects differences on the flicker task, participants detected more quickly central compared to marginal interest changes, which replicates findings from Rensink et al. (1997) and Cohen and Shapiro (2007). Also, the finding was replicated from Rensink et al. (1997) and Cohen and Shapiro (2007) that detection of marginal interest changes took significantly longer than central interest changes for each change type. Rensink et al. (1997) did not compare performance between change types (presence/absence, color, location). However, such comparison by Cohen and Shapiro (2007) revealed that the mean number of cycles needed to detect change increased by change type (increasing in the order of color, presence/absence, and location) for marginal interest changes, but changed only slightly across central interest change types. That is, observers detected different change types of marginal interest with variable facility. A similar pattern emerged in the current study, with participants needing increasing cycles to detect changes of presence/absence and location compared to changes of color for marginal interest changes, but needing a comparable number of cycles to detect central interest changes. Future research on marginal interest change types may provide further insight regarding focused attention. For example, the variable facility of detection for marginal interest change types may be specific to Rensink et al.'s (1997) stimuli, although future replication of this finding with a different stimuli set may indicate that focused attention indeed operates differentially for change types of marginal interest. Overall, the replication and extension of Rensink et al.'s (1997) work with adults (Cohen & Shapiro, 2007) and children (current study) provide further support for the robust nature of the change blindness phenomenon and for using the flicker task to demonstrate this phenomenon.

Regarding diagnostic group differences on the flicker task, and contrary to current predictions, children with ADHD demonstrated *faster* RT (fewer cycles) with *less* variability in detecting change for the most difficult degree (i.e., marginal interest) and type (i.e., location) of changes. Equivocal results for RT group differences in the CCPT literature (Epstein et al., 1998) seemingly would render the present RT group difference relatively uninteresting. However, this RT group difference skewed in the unexpectedly opposite direction, whereby children with ADHD displayed faster RT compared to the control group. More striking is the result related to variability of RT. Various CCPT studies with children (Epstein et al., 2003) and adults (Murphy et al., 2001; Walker et al., 2000) have produced such group difference, and a recent meta-analysis of the stop-signal CPT suggested that variability in RT may be a hallmark of childhood (but not adult)

ADHD (Lijffijt, Kenemans, Verbaten, & van Engeland, 2005). The unexpected results for RT and variability of RT likely may be explained by a speed/accuracy performance tradeoff. Consistent with current prediction, the ADHD group demonstrated marginally lower accuracy (increased commission errors) compared to the control group, which corresponds to Cohen and Shapiro's (2007) finding that adults with ADHD made significantly more commission errors than the control group. Taking together flicker task performance for RT, variability of RT, and accuracy, the ADHD group likely achieved faster RT and reduced variability of RT at the expense of decreased accuracy (i.e., omissions). Such a speed/accuracy tradeoff has been observed in a variety of visual search task (Lobaugh et al., 1998) and CPT (Hervey et al., 2006) studies with normal and ADHD populations, respectively.

The unexpected findings of decreased RT and variability of RT by the ADHD group offer other implications. These findings contradict a recent review by Rommelse, der Stigchel, and Sergeant (2008) on eye movement studies in childhood—all utilizing eye-tracking equipment—which documented a relatively small but reasonably strong literature indicating that children with ADHD demonstrate a consistently reduced ability to suppress unwanted saccades and to control voluntary behavior. Specific to the flicker task, O'Regan and colleagues (2000) used eye-tracking hardware to evaluate adult eye movements and visual search style during flicker task administration. Even when observers searched actively (at times, for close to 1 min) for changes in the scene, the eye continued to follow a surprisingly stereotyped, repetitive scanpath—centered on central interest features—in which large areas of the scene—marginal interest features—were never directly fixated. Analysis of eye movements showed, as expected, that the probability of detecting a change depended on the eye's distance from the change location. However, a surprising finding was that, for both central and marginal interest changes, even when observers were directly fixating the change locations (within 1 degree), they still failed to detect the change more than 40% of the time. That is, looking at something does not guarantee that you "see" it. Findings from O'Regan et al. (2000) provide two hypotheses that may help to explain the ADHD group's superior change detection of marginal interest changes. First, it appears that children with and without ADHD have equivalent ability to detect change in the strictest sense (i.e., fixate an object before and after a change, in order to compare any difference and determine that a change has occurred), given the comparable performance between the ADHD and control group for central interest items. Second, as described above, given the decreased control of voluntary eye movements observed in children with ADHD (Rommelse et al., 2008), it follows that children with ADHD may perform poorly on complex tasks requiring systematic search.

A recent computer-based study of visual discrimination involving children with and without ADHD provided evidence for this latter hypothesis (Sonuga-Barke, Elgie, & Hall, 2005). Compared to the control group, children with ADHD spent less time attending to stimuli, searched in a less intensive and less systematic way when they were actively on task, and ultimately identified fewer targets. Similarly, it is possible that children with ADHD in the current study did not utilize the typically stereotyped, repetitive scanpath that centers central interest features. Instead, they may have utilized a less systematic, more disorganized scanpath, which ironically happened to serve as the ideal visual search strategy to identify marginal interest changes in the flicker task. However, a limitation cited by Sonuga-Barke et al. (2005) is identical to that acknowledged presently: the absence of eye-tracking equipment to examine the observer's visual scanpath. Although a limitation at present, the inclusion of eye tracking may provide a worthy direction for future flicker task research regarding children with ADHD.

Returning to between-group differences in accuracy, the youngest age group (6-8 years) made more commission errors compared to the two older age groups (9-10 and 11-12 years), an age effect that is consistent with this age group making more errors than older children during visual search (Lobaugh et al., 1998). However, this age effect did not influence flicker task results, as increased errors for the youngest group did not vary by diagnostic group. Also, inconsistent with current prediction, there was no group difference for omission errors. This result is not surprising, given the absence of a group difference for omission errors in Cohen and Shapiro (2007). Both the current study and that by Cohen and Shapiro (2007) established a 2-min time limit to reduce excessive frustration experienced by inability to detect the change. Inadvertently, increasing the time limit to avoid participant frustration inherently decreased the opportunity for participants to "time out" after 2 min (i.e., commit an omission error).

The flicker task is posited to be a measure of focused attention, such that performance may be expected to fluctuate over time. However, performance over time did not vary by diagnostic group for any dependent variable. Instead, performance over time varied only for variability of cycles needed to detect change, which decreased across two time blocks for both diagnostic groups. It is possible that flicker task changes were not difficult enough to detect or that the number of stimuli was not sufficiently large to tax the mechanisms of focused attention. Alternatively, other cognitive factors—including other attentional processes such as alertness and encoding, executive control processes such as goal directedness and motor control, or visual processes such as discrimination and spatial analysis—may have influenced performance leading to the absence of additional between-group differences. The hypothesis that enhanced complexity and ecological validity of the flicker task compared to the CCPT would elicit diagnostic group differences was not supported. Instead, the increased realism of the flicker task stimuli may have reduced the attentional difficulties of the ADHD group, thereby enhancing performance of the ADHD group. Thus, the enhanced appearance of the flicker task may have produced an effect similar to a study by Shaw et al. (2005) demonstrating that children with ADHD showed improved performance on a game-like version of the CCPT compared to the less stimulating, standard CCPT. Shaw et al. (2005) found that, compared to a control group, children with ADHD spent less time on-task and made more commission errors on the CCPT. However, on a game-like analog of the CCPT—with Pokémon characters replacing CCPT letters—children with ADHD showed a significant decrease in commission errors and a significant increase in on-task activity. Further, the control group's performance did not improve on the game-like CCPT task, although ADHD performance increased to match that of the control group. Shaw et al. (2005) suggested that the lack of performance improvement for the control group indicated that the effect was specific to children with ADHD, and did not result from universally applicable appeal and effects of computer games. Shaw et al. (2005) noted that their findings did not challenge claims that individuals with ADHD demonstrate difficulties with inhibition. Rather, they suggested that contexts exist in which ADHD inhibitory performance may be enhanced.

Comparison of the Flicker Task and CCPT. Flicker task and CCPT sensitivity and specificity are similar, despite the fact that the CCPT generated more between-group differences than did the flicker task. Three diagnostic group differences emerged for the flicker task. In comparison, seven diagnostic group differences emerged for the CCPT, as derived from the initial MANOVA that yielded a non-significant multivariate main effect of diagnostic group (although only four between-group differences emerged when using the conservative follow-up MANOVA, which did produce a significant multivariate main effect). This disparity in between-group differences may suggest that children with ADHD have greater difficulty with tasks of disinhibition compared to tasks of focused attention. However, a meta-analysis of the response inhibition stop-signal CPT provided evidence that children with ADHD demonstrate a deficit in the domain of attention rather than response inhibition (Lijffijt et al., 2005). Similarly, it may be possible that children with ADHD do not show a great number of deficits on various types of focused attention tasks, such as the flicker task. Regardless, the similar sensitivity and specificity of the flicker task and CCPT provide a strong counterargument to the notion that children with ADHD demonstrated greater difficulty on the CCPT compared to the flicker task. An additional counterargument is the fact that only one variable for each task remained in its respective final logistic regression equation (used to determine discriminative utility). Instead, the disparity in between-group differences may be due to differential task demands. That is, the CCPT is a response inhibition (go/no go) task, whereas the flicker task is a focused attention (go) task. Virtually all CPTs that are commercially available and/or used in research studies are variants of the response inhibition paradigm (Riccio et al., 2001). Thus, future studies may include CPTs that isolate mechanisms of focused attention, which will allow comparison of between-group differences for go and go/no go CPTs.

In terms of discriminative utility and between-group differences, it is doubtful that a CPT will produce a single robust measure of attention that will serve to differentiate individuals with and without ADHD, especially given the multidimensional nature of both attention as a construct and ADHD as a diagnosis. Thus, researchers and clinicians are left to examine the convergence of significant dependent variables on a given CPT when trying to determine the presence of attentional difficulties, which the CCPT Confidence Index was designed to reflect and what individuals are encouraged to do when interpreting CPT results (Conners & MHS Staff, 2002). Also, researchers and clinicians must continue to examine performance on multiple measures. For example, discriminative utility in the present study was best when combining dependent variables from both the flicker task and CCPT.

Correlations Between Flicker Task and CCPT Dependent Variables and CPRS Scores

Examination of bivariate correlations (as well as the lack thereof) among CPRS scores and flicker task and CCPT dependent variables provides further understanding of these two tasks of attention in relation to ADHD symptomatology. Regarding the flicker task and CPRS scores, mean number and variability of cycles for marginal interest changes (overall and for the second half of the administration) and for changes in location were significantly correlated (for all but one association) with ADHD symptomatology (both inattention and hyperactivity/impulsivity). These significant correlations reflect findings discussed above, specifically that the visual processing deficits observed in children with ADHD likely, and surprisingly, facilitated their decreased RT and variability of RT needed to detect change for the most difficult degree (i.e., marginal interest) and type (i.e., location) of change. In addition, mean commission errors (overall and for the first half of the administration) were significantly correlated with ADHD symptomatology (both inattention and hyperactivity/impulsivity). Regarding the CCPT and CPRS scores, Confidence Index, omission errors, HIT RT, HIT RT SE, and variability were significantly correlated with ADHD symptomatology (both inattention and hyperactivity/impulsivity). That is, significant correlations with dependent variables of these two tasks frequently associated with CPRS indices of both inattention and hyperactivity/impulsivity, thus indicating a lack of symptom domain specificity of CPT measures.

This lack of symptom domain specificity corresponds well to an epidemiological study of children (Epstein et al., 2003) as well as adult studies (Solanto et al., 2004), all of which did not find predicted symptom domain specificity of CCPT measures. Solanto et al. (2004) suggested that vigilance, effortful processing, and self-inhibition may be part of a larger self-modulatory system that influences symptom presentation, regardless of specific symptoms cluster. In contrast, other studies with children (Edwards et al., 2007; McGee et al., 2000; Weis & Totten, 2004) and adults (Epstein et al., 1998) found no significant correlations between CCPT measures and ADHD symptomatology. Epstein et al. (1998) cited this result as common to both child and adult CPT literature and suggested that the lack of correlation may suggest that CPT performance may not directly correspond to behavioral manifestations of similar constructs, an interpretation disputed by the current findings. There were no interpretatively useful significant correlations between parallel performance measures of the flicker task and CCPT, given that the only significant correlation was a relationship between CCPT omission errors (theoretically linked to inattention) and flicker task commissions (theoretically linked to hyperactivity/impulsivity). Overall, the lack of significant correlations suggests the dissimilarity of measured constructs. As noted above, both tasks are posited to assess attentional processes, but employ different task demands that likely tap different aspects of attention and other cognitive processes.

Limitations

There are several limitations of the study. First, inclusionary criteria for individuals in the ADHD group may have increased variability within the sample. The ADHD group was defined as parents who reported a current ADHD diagnosis and significant levels of current ADHD symptoms for their child (based on CPRS scores). This method of diagnostic group assignment is consistent with Pelham and colleagues' (2005) rationale that research studies require only a *DSM*-based diagnostic scale in order to establish the diagnosis for study inclusion. Thus, the present study did not include other aspects advocated to reflect a more comprehensive diagnostic process: a structured diagnostic interview used to recognize developmental differences in child ADHD symptom expression and to provide a differential diagnosis; and multi-informant interviews (usually including parents and teachers) to corroborate the presence of symptoms across contexts (Barkley, 2006; McGough & Barkley, 2004). Also, all three DSM-IV ADHD subtypes were combined to form the ADHD group. Thus, the ADHD sample in this study may have been more heterogeneous than a rigorously defined ADHD sample using strict diagnostic criteria. Second, the ADHD and control group were not matched on variables that may have affected performance on CPTs (e.g., IQ, psychopathology; Epstein et al., 1998). Specific to IQ, Frazier et al. (2004) conducted a meta-analysis regarding intellectual functioning and ADHD and found that, consistent with research suggesting medium to large differences in overall ability, individuals with ADHD obtained FSIQ scores approximately 9 points (*SD* = 0.61) below the mean for comparison groups. Accordingly, Frazier et al. (2004) and other prominent ADHD researchers (Barkley, 2006) have argued that decreased cognitive functioning is characteristic of ADHD. In this manner, IQ was not considered in the present study based on the rationale that controlling for IQ may have eliminated other related aspects that are characteristic of ADHD functioning. Specific to psychopathology, the screening procedure (i.e., exclusion of individuals reporting current use of long-term psychoactive medications) and matching protocol (for age and sex) may have informally and partially controlled for psychopathology. Third, as noted above, the flicker task time limit used to avoid participant frustration inherently decreased the opportunity for participants to "time out" after 2 min (i.e., commit an omission error). Fourth, researchers were not blind to participants' diagnostic group membership, which may have influenced participant performance. Fifth, the current study can generalize only to a primary school sample.

Summary and Future Directions

Children with and without ADHD appear to exhibit comparably variable levels of attention and hyperactivity/impulsivity deficits, as measured by the flicker task and CCPT. However, the generally weak sensitivity and specificity of both tasks render them less than ideal measures for making discriminative and/or diagnostic decisions. The poor discriminative utility of these two tasks highlights the need for future research to explore and understand more fully the attentional difficulties and performance challenges associated with ADHD, as well as to continue designing and refining measures to differentiate children with and without ADHD. Regarding the flicker task, future studies may remove the time limit for detecting change and may add more stimuli, thereby elongating the flicker task, which may more rigorously tax the abilities of children with attentional difficulties and test the limits of focused attention. Also, future flicker task studies may include additional marginal interest stimuli, which may provide a better understanding of focused attention. Rensink et al. (1997) provided valid and invalid cues during flicker conditions, which enhanced and decreased facility of detection, respectively. Future flicker task studies may examine how differential cues influence performance of children with and without ADHD. Regarding both the flicker task and CCPT, more longitudinal studies are needed to examine the developmental course of CPT performance, such that children and adults with ADHD may show differential deficits in CPT performance. For example, Lijffijt et al. (2005) suggested that children with ADHD demonstrate a deficit in general inattention on the stop-signal CPT, whereas adults with ADHD demonstrate a deficit in inhibitory motor control. In addition, future research should examine using the flicker task and CCPT to detect treatment outcome for individuals with ADHD, such as medication response.

The present study replicates and extends findings from Rensink et al.'s (1997) seminal work, providing further support for using the flicker task to demonstrate the robust nature of change blindness. In addition, the present study replicates findings from Cohen and Shapiro's (2007) study, contributing to the handful of flicker task studies that target clinical populations, and extends the understanding of change blindness and the flicker task from the adult to the child domain. Taken together, findings from Cohen and Shapiro (2007) and the present study provide evidence that, compared to the widely used CCPT, the flicker task provides similarly insufficient utility for discriminating children and adults with and without ADHD. This finding adds support to the growing evidence that CPTs—ranging from relatively unknown and untested versions such as the flicker task to well known and commercially available variants such as the CCPT—currently provide minimal utility for making discriminative and/or diagnostic decisions regarding disorders of attention. If CPTs are to be used as diagnostic tools, future research must continue to manipulate and compare computerized measures of attention in order to create a CPT that taps a specific cognitive mechanism (of attention, response inhibition, etc.) as well as differentiates individuals based on that mechanism.

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APPENDIX A

Demographic questionnaire.

Parent Orientation Letter

Participant Contact Information/Demographics Questionnaire

Notice: This information will remain strictly confidential
and will be destroyed at the completion of the study.

Dear Parent/Guardian,

My name is Andy Cohen and I am a graduate student at Auburn University. I am pursuing a Ph.D. in clinical child psychology and, in order to finish my degree, I am required to complete a research project. For my project, I am interested in examining the utility of different game-like computerized and paper-and-pencil measures for children with and without Attention-Deficit/Hyperactivity Disorder (ADHD). My project has been approved by a committee of professors (directed by Dr. Steve Shapiro) in the Department of Psychology at Auburn University.

In order to complete my project, I am seeking children between the ages of 6 and 14. For parents/guardians interested in allowing their children to participate in my project, you will complete a survey packet and may be contacted later if your child is eligible to participate. If your child is selected to participate in and attends a 2-hour test session, you will receive $50 and your child will receive gift certificates worth $10.

I would greatly appreciate it if you would complete this survey packet and return it using the enclosed envelope.

Thank you for your time and consideration.

Sincerely,

Andy Cohen, M.S.
Graduate Student, Clinical Child Psychology
Department of Psychology, Auburn University

Participant Contact Information/Demographics Questionnaire

Notice: This information will remain strictly confidential
and will be destroyed at the completion of the study.

Instructions for Parents Completing this Packet

1. If possible, it is preferable for the child's ***maternal guardian*** to complete this packet.

2. This research opportunity is intended for ***children with or without ADHD***.

3. ***If your child currently takes prescribed medication for ADHD,*** please mark the items on the Conners' Parent Rating Scale regarding what your child's behavior is like when s/he has ***NOT*** taken his/her medication.

4. ***Please return the stapled packet*** in the self-addressed stamped envelope. Thank you!

Participant Contact Information/Demographics Questionnaire

Notice: This information will remain strictly confidential
and will be destroyed at the completion of the study.

Parent Name: ____

Child Name: ____

Parent Home Phone: ____

Parent Cell Phone: ____

Parent Work Phone: ____

Parent Email: ____

I prefer to be contacted by _____ Phone _____ Email _____ Either

Participant Contact Information/Demographics Questionnaire

Notice: This information will remain strictly confidential
and will be destroyed at the completion of the study.

Child Age:

____

Child Date of Birth:

(MM/DD/YY) _____ / _____ / _____

Child Sex: (circle one)

1=Male 2=Female

Child Race: (circle one)

1= Caucasian
2=African-American
3=Hispanic
4=Asian
5=Native American
6=Mixed (specify) _______________
7=Other (specify) _______________

Has your child **ever** received an ADHD diagnosis from a physician or psychologist? (circle one)

1=Yes 2=No

Is your child **currently** diagnosed with ADHD by a physician or psychologist? (circle one)

1=Yes 2=No

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Participant Contact Information/Demographics Questionnaire

Notice: This information will remain strictly confidential
and will be destroyed at the completion of the study.

Has your child **ever** taken medication for ADHD? (circle one)

1=Yes 2=No

If yes, which type of ADHD medication has your child taken in the past:
(circle all that apply)

1. Adderall
2. Adderall XR
3. Attenta
4. Concerta
5. Daytrana
6. Dexedrine
7. Dexedrine SR
8. Dexedrine Spansules
9. Dextroamphetamine Sulfate
10. Dextrostat
11. Equasym
12. Focalin
13. Metadate
14. Metadate CD
15. Focalin
16. Metadate
17. Metadate CD
18. Metadate ER
19. Methylin
20. Methylin ER
21. Methylphenidate (generic)
22. Mixed Amphetamine Salts
23. Penid
24. Ritalin
25. Ritalin LA
26. Vyvanse
27. Other (specify) ______________

Does your child **currently** take medication for ADHD? (circle one)

1=Yes 2=No

If yes, which type of ADHD medication does your child currently takes:
(circle all that apply)

1. Adderall
2. Adderall XR
3. Attenta
4. Concerta
5. Daytrana
6. Dexedrine
7. Dexedrine SR
8. Dexedrine Spansules
9. Dextroamphetamine Sulfate
10. Dextrostat
11. Equasym
12. Focalin
13. Metadate
14. Metadate CD
15. Focalin
16. Metadate
17. Metadate CD
18. Metadate ER
19. Methylin
20. Methylin ER
21. Methylphenidate (generic)
22. Mixed Amphetamine Salts
23. Penid
24. Ritalin
25. Ritalin LA
26. Vyvanse
27. Other (specify) ______________

Participant Contact Information/Demographics Questionnaire

Notice: This information will remain strictly confidential
and will be destroyed at the completion of the study.

Has your child **ever** taken medication for a psychological problem (antidepressant, antianxiety, antipsychotic)?
If unsure, just list any medication(s) that your child has taken in the past for a psychological problem. (circle one)

1=Yes 2=No

If yes, write the name of the medication(s) your child has taken in the past:

____________________ ____________________ ____________________

____________________ ____________________ ____________________

Does your child **currently** take medication for a psychological problem (antidepressant, antianxiety, antipsychotic)?
If unsure, just list any medication(s) that your child currently takes for a psychological problem. (circle one)

1=Yes 2=No

If yes, write the name of the medication(s) your child currently takes:

____________________ ____________________ ____________________

____________________ ____________________ ____________________

Does your child have normal vision? (circle one)

1=Yes 2=No

If your child does **not** have normal vision, does s/he wear glasses or contacts? (circle one)

1=Yes 2=No

Does your child have colorblind vision? (circle one)

1=Yes 2=No

Does your child have any of the following: seizures, schizophrenia, brain damage? (circle one)

1=Yes 2=No

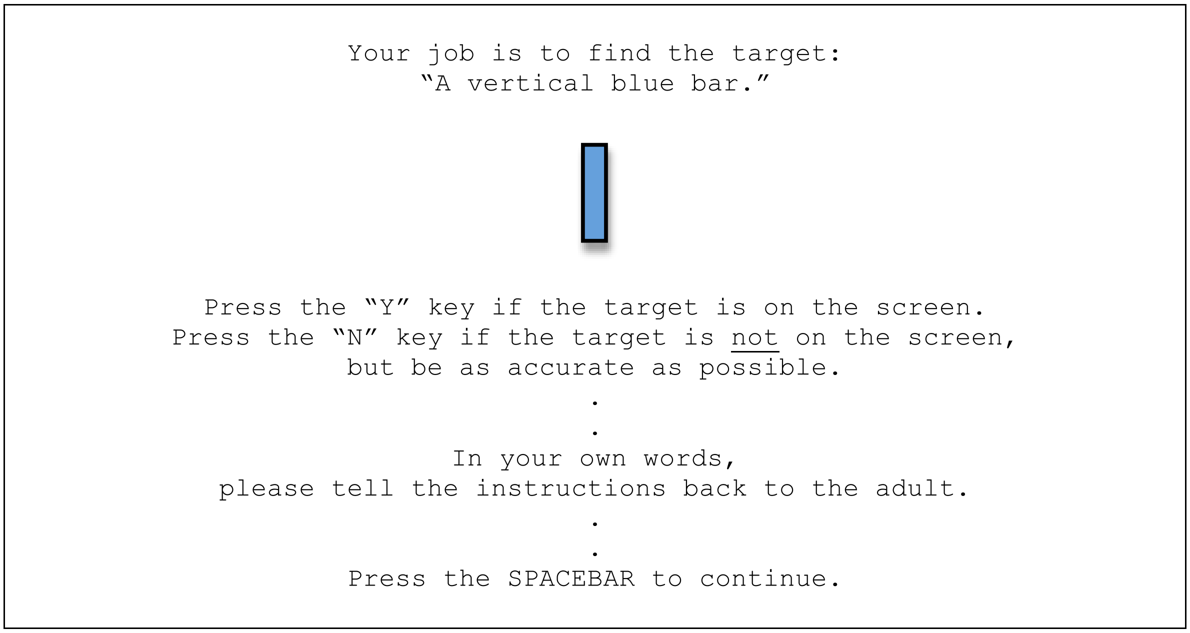
If yes, please specify:

____________________ ____________________ ____________________

APPENDIX B

Visual search task instructions, for both practice and test blocks.

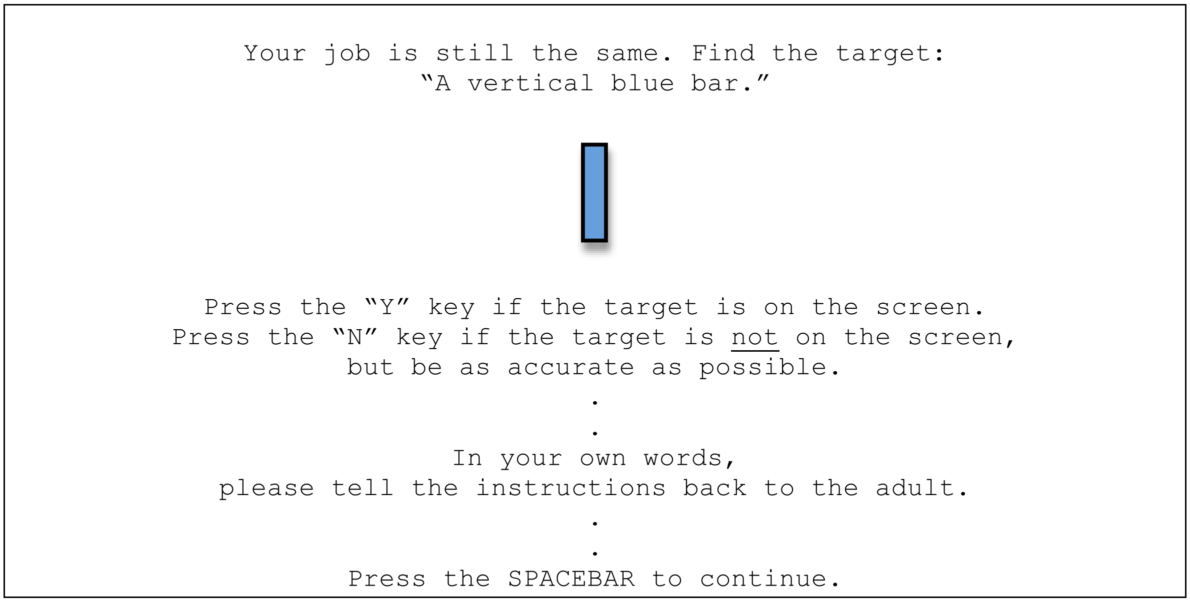
Practice block instruction screen A.



Your job is to find the target:
"A vertical blue bar."

Press the "Y" key if the target is on the screen.
Press the "N" key if the target is not on the screen,
but be as accurate as possible.
.
.
In your own words,
please tell the instructions back to the adult.
.
.
Press the SPACEBAR to continue.

Test block instruction screen A.



Your job is still the same. Find the target:
"A vertical blue bar."

Press the "Y" key if the target is on the screen.
Press the "N" key if the target is not on the screen,
but be as accurate as possible.
.
.
In your own words,
please tell the instructions back to the adult.
.
.
Press the SPACEBAR to continue.

APPENDIX C

Flicker task instructions, for both practice and test blocks.

Practice block instruction screen A.

You will see a series of pictures.
Each picture will flash onscreen.

A change may occur to the picture.
For example, an object or region in the picture
may change color, change location, or appear/disappear.
There will be only one change per picture.

Your task is to determine when the picture changes.
As soon as you see the change, press the SPACEBAR.

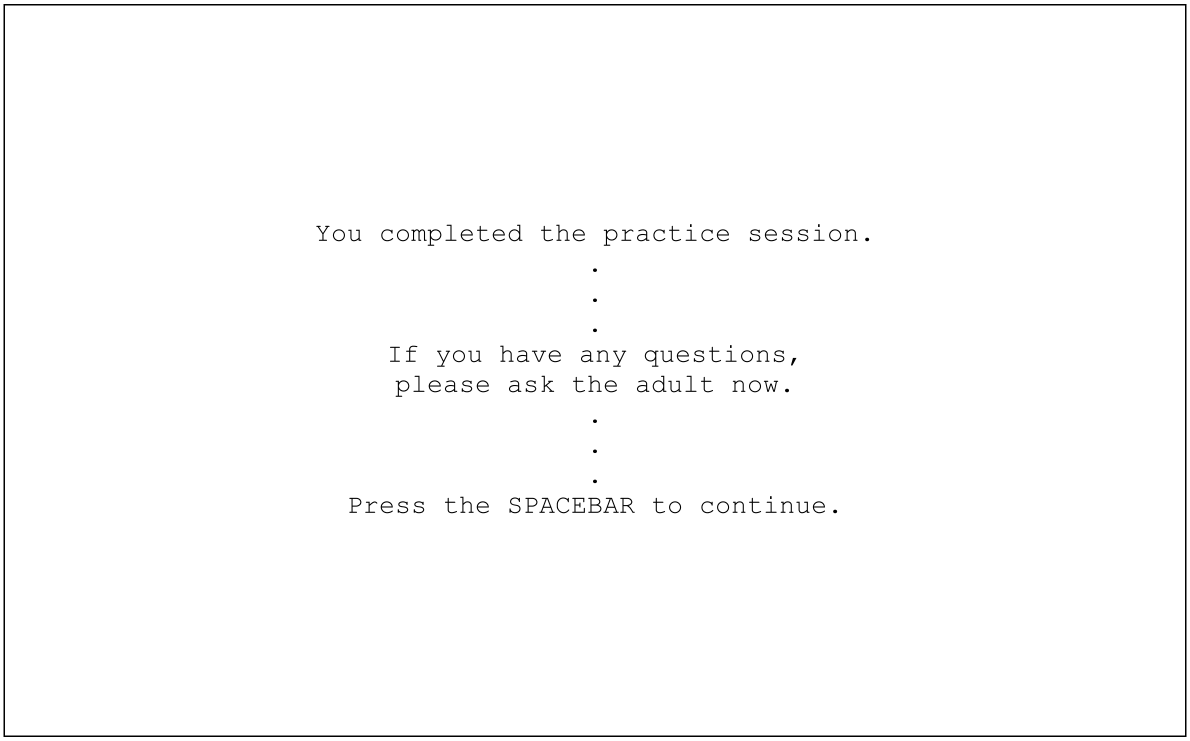
You will then report the change to the adult.
.
.

In your own words,
please tell the instructions back to the adult.
.
.
.
Press the SPACEBAR to continue.

Practice block instruction screen B.

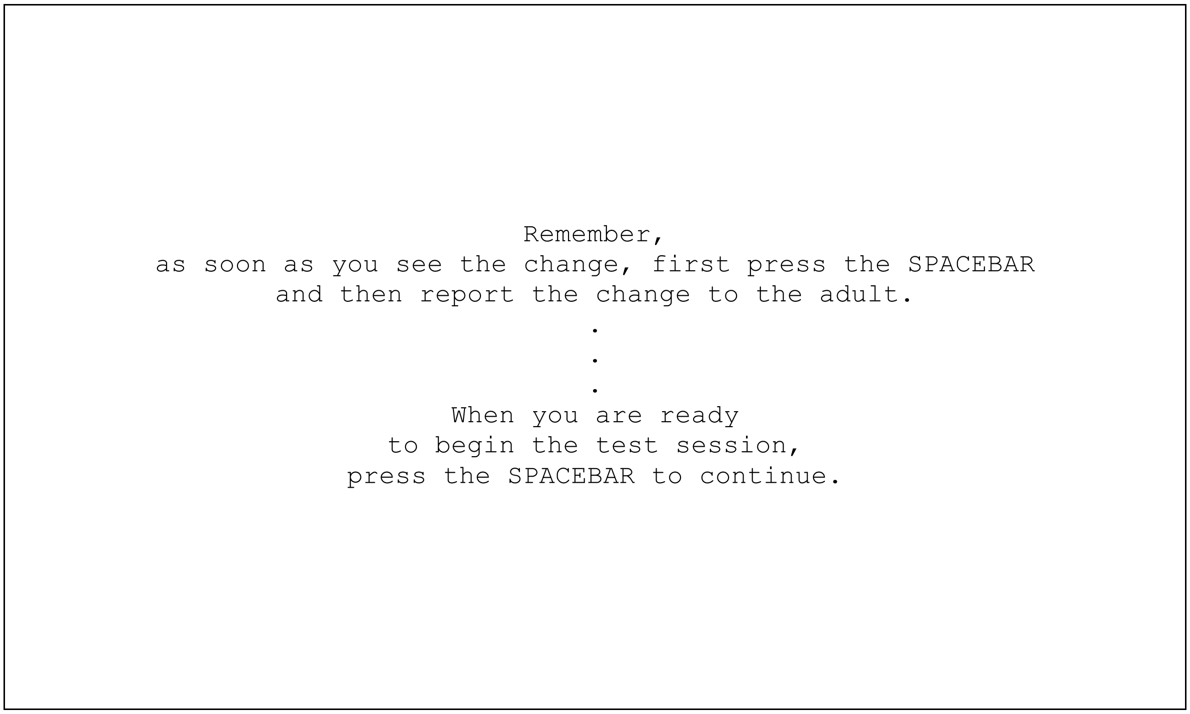
If you have any questions,
please ask the adult now.
.
.
.
When you are ready
to begin the practice session,
press the SPACEBAR to continue.

Test block instruction screen A.



You completed the practice session.
.
.
.
If you have any questions,
please ask the adult now.
.
.
.
Press the SPACEBAR to continue.

Test block instruction screen B.

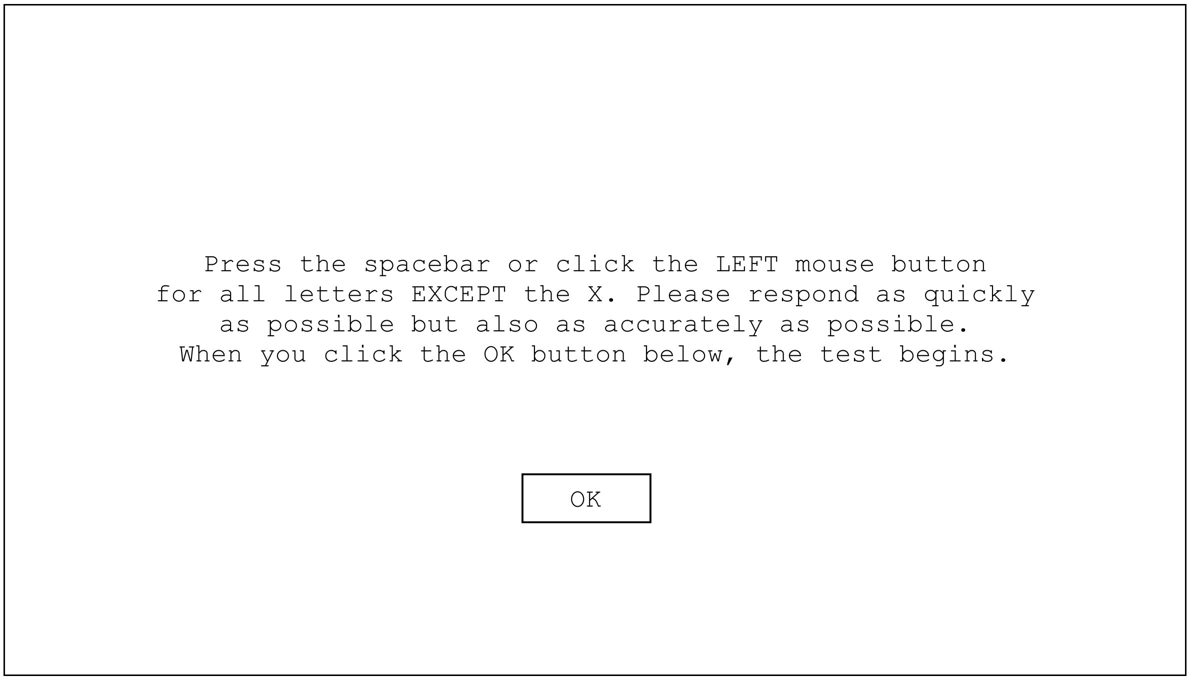


Remember,
as soon as you see the change, first press the SPACEBAR
and then report the change to the adult.
.
.
.
When you are ready
to begin the test session,
press the SPACEBAR to continue.

APPENDIX D

CCPT instructions, for both practice and test blocks.

Practice and test block instruction screen.



Press the spacebar or click the LEFT mouse button
for all letters EXCEPT the X. Please respond as quickly
as possible but also as accurately as possible.
When you click the OK button below, the test begins.

After the practice block instructions, the administrator stated to the participant, “Ignore the instructions regarding the left mouse button and use only the spacebar. Now please tell the instructions back to me in your own words.” After the practice block, the administrator asked the participant, “Do you have any questions?” The administrator clarified task demands as needed.