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The effects of continuous and partial reward on the vigilance task performance of adults with attentional deficits: A pilot investigation

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Abstract

The effects of reward schedule (100% and 30%) and extinction on attention (reaction time to auditory stimuli) and frustration levels (pressure exerted on a response key) of 15 adults with attentional disorders and 21 normal adults were examined using a continuous performance task. We predicted, based on Douglas and Parry ((1994). *Journal of Abnormal Child Psychology*, *22*, 281), that adults with attentional deficits would (a) perform similar to comparisons when rewarded on a continuous schedule, (b) exhibit higher levels of frustration when that continuous schedule was moved to an extinction schedule, and (c) experience more frustration than comparisons when rewarded on a partial schedule. Overall, adults with attentional deficits were slower to respond and their responses were more variable than typical comparisons across trials, similar to what is observed for children. Continuous reward resulted in poorer performance earlier in the reward phase and continued throughout an extinction phase. The frustration levels of adults with attentional deficits did not differ from comparisons across schedule conditions. Results are discussed in terms of the role of arousal in mediating responding to various schedules of reward.

Keywords: Attention deficit; Persistence; Reward

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1. Introduction

Children with attention deficit hyperactivity disorder (ADHD) often demonstrate significant educational (Zentall, 1993) and behavioral deficits (Barkley, DuPaul, & McMurray, 1990; DuPaul & Stoner, 1994). Prevalence estimates suggest that 1–2% of all adults may have ADHD (Shekim, Asarnow, Hess, Zaucha, & Wheeler, 1990). During adulthood, ADHD can lead to difficulties in interpersonal, academic, and occupational functioning. For example, long-term outcomes include less schooling and lower ranking occupational positions than comparisons (Mannuzza, Klein, Bessler, Malloy, & Hynes, 1997). Over the course of the disorder there is greater risk for developing mood disorders, substance abuse, and antisocial behavior (Biederman, Munir, & Knee, 1987; Biederman et al., 1987; Gomez, Janowsky, Zetin, Huey, & Compton, 1981; Tartar, McBride, Buonpane, & Schneider, 1977).

Because of the long-term effects of ADHD, researchers have attempted to isolate the variables thought to be responsible for the long-standing performance deficits. Two lines of research have emerged from these investigations—one focusing primarily on executive functioning (e.g., Barkley, 1997) and the second on motivational variables (e.g., Sagvolden & Sergeant, 1998).

Researchers investigating the motivational aspects of ADHD have found that children with ADHD respond differently to reward contingencies than typical peers (Douglas, 1985; Tripp & Alsop, 2001). Two procedural variants have been used to examine these effects. In the first, children with ADHD are asked to perform a task for an immediate (usually small) or a delayed (usually larger) reward. This research indicates that children with ADHD prefer smaller immediate over larger delayed rewards (e.g., Rapport, Tucker, DuPaul, Merlo, & Stoner, 1986; Tripp & Alsop, 2001). In explaining these findings Johansen, Aase, Meyer, and Sagvolden (2002) suggested that children with ADHD have a steeper and shorter delay of reinforcement gradient, as well as altered extinction processes. That is, the responding of children with ADHD decreases more rapidly than typical children when there is a delay in the delivery of reinforcement. When rewards are discontinued, such as during an extinction procedure, children with ADHD may continue to respond, whereas the responding of typical peers may decrease. Barkley (1997) similarly suggested that children with ADHD were unable to bridge the temporal gap between a response and reward. More recently, Sonuga-Burke (2002, 2003) proposed a dual pathway model of ADHD. According to this model, ADHD is caused by both executive and motivational dysfunction. More specifically, children with ADHD fail to inhibit responding (executive) and are delay aversive (motivational). Children with ADHD avoid situations associated with delay of reward and may have difficulty working for delayed consequences. Thus, the impulsivity that characterizes children with ADHD is an attempt to minimize delay and maximize overall levels of reward.

In the second procedural variant, quantity of reward is manipulated by providing rewards on continuous (i.e., every response is rewarded) or partial (i.e., rewarding some, but not all responses) schedules of reward. Although the findings have been inconsistent, procedural artifacts appear to moderate the effects of these different schedules on performance and behavior. That is, failure to find differences between children with and without ADHD who were rewarded according to a partial schedule (i.e., intermittent) (a) on a discrimination-learning task (Cunningham & Knights, 1978), (b) on a nonsense-spelling task (Pelham, Milich, & Walker, 1986), and (c) a paired-associate memory task (Barber, Milich, & Welsh, 1996) could be attributed to the fact that students in all three studies were told they would receive a reward for some, but not all correct answers in the partial reward condition. Providing information on the probability of receiving a reward may have resulted in reduced reward expectancy for the partial reward group (i.e., there may not have been a discrepancy between the number of rewards expected and the number of rewards received). As well, the children in the Pelham et al. study were given added verbal praise for correct answers across schedule conditions (i.e., concurrent schedules of reward) that might have been enough reward to maintain the performance of children with ADHD during the partial schedule of reward, thereby making direct schedule comparisons less meaningful.

Other researchers (e.g., Douglas & Parry, 1994) have found differences in responding between children with ADHD and typical peers when the quantity of reward was changed through nonreward, continuous, and intermittent reward conditions. These researchers reported poorer performance on partial than on continuous schedules. Specifically, on attentional and delayed reaction time tasks, continuous schedules of reward led to enhanced performance and reduced variability in responding, compared with partial schedules of reward (Douglas & Parry, 1983; Freibergs & Douglas, 1969; Parry & Douglas, 1983). As well, when concept task performance was rewarded on a continuous schedule, children with ADHD performed at levels equivalent to comparisons, but differed from comparisons when rewarded on a partial schedule (Parry & Douglas, 1983).

To explain the differential effects of reward on behavior and performance Douglas (1985) suggested arousal as the underlying mechanism that mediates responding to different reward schedules. Children with ADHD have an unusually strong need for immediate reward, and therefore (a) are unusually vulnerable to possible arousing and distracting effects of reward and (b) become abnormally frustrated when expected rewards fail to appear (Douglas & Parry, 1994). Douglas and colleagues (Douglas & Parry, 1983, 1994; Freibergs & Douglas, 1969) have drawn upon Amsel's arousal-based frustration theory. Amsel (1958) proposed that emotion, specifically frustration, governs task persistence. According to Amsel, an individual on a given reward schedule develops an expectancy of reward (anticipatory reward). When this reward is withheld (e.g., during nonrewarded trials of a partial schedule), the individual experiences "primary frustration." During subsequent trials, the individual approaches the task with an expectancy of both reward and frustration (anticipatory frustration). Through a process termed "counterconditioning" the individual learns to respond in the presence of anticipatory frustration. According to Amsel's theory, the behavior of individuals who have been successfully counterconditioned is more resistant to extinction, because responding continues to occur in the presence of anticipatory frustration. In terms of Amsel's theory of persistence, persons with ADHD may fail to countercondition, because their excessive focus on reward tips the balance of reward expectancy and frustration toward frustration.

To demonstrate this bias toward frustration as a possible explanation for the schedule performance of children with ADHD, Douglas and Parry (1994) used a lever-pulling task to assess both attention and frustration. Attention was assessed using latency of response (i.e., time from the onset of a target stimulus to the participant's response). Frustration was assessed by measuring the duration of a lever pull (i.e., participants who pulled the lever more vigorously had shorter lever pull durations, which were indicative of greater frustration). Findings indicated that the reaction times (attention) of the ADHD and comparison groups were similar during a continuous reward condition. On a partial schedule of reward, however, reactions times of comparisons were faster than those of the ADHD group. Planned comparisons indicated that children with ADHD also experienced more frustration (i.e., shorter lever pull durations) than comparisons during partial reward. When continuous reward was withdrawn during extinction, the ADHD group experienced higher levels of frustration than the comparison group.

Although the generality of these frustration effects has been established with a different measure of frustration (facial expression) (Wigal et al., 1998), they have not been assessed with adults. This study was designed to investigate whether continuous and partial schedules of reward would differentially affect the attention and frustration of adults with and without attentional deficits, as it does with children. Specifically we predicted, based on the work of Douglas and colleagues, that adults with attentional deficits would (a) perform worse and exhibit higher levels of frustration than comparisons when rewarded on a partial schedule, (b) perform similar to comparisons when rewarded under a continuous schedule, and (c) perform worse and exhibit higher levels of frustration during an extinction phase that followed continuous reward.

2. Methods

2.1. Participants

Forty-three college-age students were recruited through announcements in classes for research credit in educational psychology and from flyers posted in education and psychology departments. The announcements and flyers specifically stated that adults with and without attentional disorders were needed to participate in a study. Participants in this initial group were asked to complete three assessment instruments. First, participants were asked to complete the Brown Attention-Deficit Disorder (ADD) Scale for Adults (Brown, 1996). The Brown Scale contains 40 self-report items that are clustered according to the following categories: (a) organizing and beginning a task, (b) sustaining attention and concentration, (c) sustaining energy and effort, (d) managing affective interference, and (e) utilizing "working memory" and accessing recall (for norms, validity data, and reliability data, see Brown, 1996; Muniz, 1996). Kaufman, Kaufman, and Newman (2001) reported that the Brown Scale has exceptional discriminant validity. The norms for this scale were developed from a total sample of 285 adults (143 nonclinical and 142 clinical). Thirty-six percent of the sample was between 18 and 28 years of age. The author reports coefficient alphas of .86 for clinical and .93 for nonclinical groups. Evidence of concurrent validity was demonstrated as a relationship between three subtests on the WAIS-R (Digit Span, Arithmetic, and Digit Symbol) that are commonly associated with symptoms of ADD and the Brown Scale.

Because the Brown Scale for Adults primarily assessed deficits in attention, participants were also asked to complete two rating scales based on the nine DSM-IV hyperactivity-impulsivity criteria for ADHD (American Psychiatric Association, 1994). For the first rating scale, each participant was asked to rate, on a Likert-type scale, the presence of the nine hyperactivity–impulsivity symptoms from 0 (not at all) to 3 (very much), as they currently applied to that participant (adult scale) and the second rating scale as they applied to that participant as a child (childhood scale).

The Brown ADD Scale was used to select and assign participants to groups. The attentional deficit group was defined by raw scores at or above 50 on the Brown Scale, whereas the comparison group scored below 40. Brown (1996) recommended that a raw score of 50 be used as a clinical cut score, because it indicates a high probability of ADD; whereas, it is unlikely that an individual who scored below 50 would meet the diagnostic criteria for ADD.

This assignment procedure resulted in 15 adults in the attentional deficit group (4 men and 11 women) and 21 adults in the comparison group (6 men and 15 women). The two groups differed on both the DSM-IV and the Brown ADD checklists, which were used in the formation of the groups (see Table 1), but no group differences in age or grade point average were found. Although the number of females was greater than that of males, it appeared to be an artifact of our sampling procedure in which adults from education and psychology departments were recruited. Even so, males and females did not differ on the DSM-IV or the Brown ADD checklists, which is consistent with research reporting fewer gender differences

Table 1
Means, deviations standard, *F* statistics for group equivalence

	ADD		Comparisons		
	M	SD	*M*	SD	*F*
Age in months	269.93	(72.82)	276.62	(98.65)	0.05
Grade point average	3.14	(0.58)	2.98	(0.48)	0.73
Brown ADD raw scores	65.20	(11.78)	25.29	(9.93)	121.00***
Brown ADD T scores	71.79	(8.05)	51.05	(1.72)	
DSM-IV adult checklist	9.40	(5.96)	4.86	(2.63)	9.65**
DSM-IV child checklist	9.67	(6.54)	6.14	(3.51)	4.37*

*$p < .05$; **$p < .005$; ***$p < .0001$.

in adult samples (e.g., Mattes, Boswell, & Oliver, 1984; Wender, Reimherr, Wood, & Ward, 1985).

2.2. Apparatus

Participants sat at a table (1 m × 2 m) with an arm-rest containing a response key, which was positioned 30 cm back from the edge of the table. A small digital scale was positioned 10 cm to the right of the arm-rest with a felt target (6 cm in diameter) on top of the scale to ensure that participants touched the same place on the scale when responding. A partition separated the participant from the data collection equipment (e.g., timer, scale display) and from the experimenters during the study.

2.3. Task

The task was an auditory version of the continuous performance task (CPT) (e.g., Earle-Boyer, Serper, Davidson, & Harvey, 1991; Zentall & Meyer, 1987), which was introduced by a trained experimenter, who was naive to group status. The CPT is one of the most popular clinical measures of sustained attention (DuPaul, Anastopoulos, Shelton, Guevremont, & Metevia, 1992). For this vigilance task, a motor response was required to the signal letter "A," which was presented within a continuous string of an 11 additional randomly presented letters (O, T, E, C, X, M, D, S, R, G, N) using a female voice on a audio-tape player. The duration of letter presentations was approximately 0.30 s with a 1.50 s interval maintained between each letter presentation.

We modified this traditional auditory CPT by using a discrete trial format. A trial was defined as a maximum of 20 letter presentations. The signal stimulus ("A") was not placed within the first 10 letters of the trial (i.e., to offset impulsive responding and to allow habituation to task stimuli), but was randomly presented within the final 10 letters (i.e., 11–20) within each trial. Thus, the number of letters in a trial could range between 11 and 20. Throughout the 50 trials, the signal stimulus appeared at each of the 10 positions 5 times. After the presentation of the signal stimulus, a 10 s inter-trial interval (ITI) was initiated prior to the onset of subsequent trials.

2.4. Response measures

Attention to the task was assessed using response latency in ms (i.e., time from the onset of the target stimulus to the onset of the participants response using a microswitch operated timer). Frustration was assessed using grams of pressure exerted on the target located on the top of the scale. The attention and frustration measures used in this study were functionally similar to those used by Douglas and Parry (1994) who demonstrated differential effects of schedule of reward among groups. Douglas and Parry used latency of response as an attentional measure and duration of a lever pull as a measure of frustration. Children who pulled a lever more quickly over a fixed distance were said to have exhibited higher levels of frustration during the task than children with relatively longer lever-pull durations. In the present study participants who responded faster to the target stimulus were more attentive than participants with longer response latencies. Similarly, participants who exerted greater pressure on the button located on the top of the scale during a response exhibited greater frustration than participants who exerted less pressure. Variability of both reaction time and force was examined, because reward schedule has been shown to differentially affect variability of responding (Douglas & Parry, 1983).

Movement was measured using an actometer (Timex motion recorder No. 108), which was attached to each participant's dominant ankle. This device provides a reliable and valid measure of student activity (see Madan-Swain & Zentall, 1990; Zentall, 1989). Response errors within each trial were classified as: (a) omissions—no response, (b) commissions—responses to a stimulus other than the target stimulus, and (c) delayed responses—response that occurred more than 5 s after the onset of the target stimulus.

2.5. Experimental conditions and design

In this study reward was defined as positive verbal feedback. For the 50 trials presented, the participants were first given 30 reward trials (reward phase) and then 20 nonreward trials (extinction phase). For the reward phase, participants were randomly assigned to either a continuous schedule (i.e., a reward was delivered on every trial) or a 30% partial schedule of reward (i.e., rewards were randomly delivered on 30% of trials with the constraint that no more than 2 trials were rewarded in succession, and the last 2 trials of the reward phase were rewarded). Rewards were delivered immediately after the completion of a trial and were contingent upon a response (regardless of performance) using one predetermined randomly assigned partial schedule. After completion of the 30 reward phase trials, extinction trials were initiated. The participants were not informed of the change from the reward to extinction phases.

Participants within each group were randomly assigned to reward conditions [10 comparisons in the continuous reward condition (2 males and 8 females)—C/C group, 11 comparisons in the partial condition (4 males and 7 females)—C/P group, 8 students with attentional deficits in the continuous condition (2 male and 6 female)—A/C group, and 7 students with attentional deficits in the partial condition (2 male and 5 female)—A/P group]. These procedures produced a 2 group (attentional deficit and normal comparisons) $\times$ 2 schedule (continuous and partial) between-groups design. We assessed and found design equivalence in a Group $\times$ Schedule interaction using Brown Attention-Deficit Disorder Scale scores [$F(1, 32) = 1.67$, $p = .205$], as well as, the adult [$F(1, 32) = .30$, $p = .589$] and child [$F(1, 32) = .71$, $p = .406$] DSM-IV checklist scores.

2.6. Procedures

Participants were asked to complete the Brown ADD Scale, the DSM-IV checklists, a demographics questionnaire, and were then seated at the apparatus and read the following instructions:

> We want to determine the effects of getting rewards on a listening task. For this experiment you will perform a task similar to one used in training air traffic controllers. Your goal will be to win as many rewards as you can. I will signal your earning a reward by saying the word *plus*. Do you have any questions before I begin explaining the task to you?
>
> You will begin with your hand pushing down on the blue arm-rest button. A series of letters will be presented to you on a tape player. When you hear the letter "A" lift your hand from the arm-rest button, press the red target on the pad located in front of you and then return your hand to the arm rest button. Pressing the pad will reset the machine. Remember, the word plus will be used to signal a reward. Do you have any questions about the task? Let's try of few practice trials before we begin the experiment.

After the instructions had been read, three nonrewarded practice trials were initiated. Participants were given general feedback (i.e., "Yes, press the target after you hear the letter A.") after completing the three practice trials.

3. Results

Because of the variability of the participants' responses across time, reaction time (RT) and force data were averaged over ten trials to form five trial blocks from the 50 trials—three reward phase and two extinction trial blocks. Reward phase data were analyzed using mixed design: 2 Group (attentional deficit and comparison) × 2 Schedule (continuous and partial) × 3 Trial Block analyses of variance (ANOVA—GLM model adjusts for unequal groups) with group and schedule as between-group factors and trial block serving as the within-group factor. Similarly, extinction phase data were analyzed using a 2 Group × 2 Schedule × 2 Trial Block ANOVA. To analyze the simple effects of interactions, planned orthogonal contrasts were conducted for each trial block (a) between the disordered and comparison groups within each schedule and (b) between schedules for the disordered group. As indicated by Keppel (1991), the number of planned contrasts was restricted to 1 less than the number of groups and evaluated at alpha = .05 level of significance. Because of the exploratory nature of this study and our a priori prediction (i.e., that schedules of reward would differentially affect groups), planned contrasts were examined when the alpha level of the Group × Schedule × Trial Block interaction was less than .10.

3.1. Reaction time (attention)

3.1.1. Reward phase reaction time means

The ANOVA for RT yielded a significant effect of group [$F(1, 32) = 6.12$, $p = .019$, $d = .90$][1] indicating that across schedule conditions, the comparison group ($M = 654.23$, SD = 157.48) responded faster to the signal stimuli than the attentional deficit group ($M = 841.37$, SD = 281.99). A simple effects analysis of the Group × Schedule × Trial Block interaction [$F(2, 31) = 2.94$, $p = .068$] was conducted and indicated that the participants with attentional deficits, who received rewards according to a partial schedule (A/P), responded somewhat slower than comparisons on the same partial schedule (C/P), but only on the third trial block, $F(1, 32) = 5.95$, $p = .053$, $d = .96$ (A/P $M = 984.48$, SD = 369.63; C/P $M = 736.63$, SD = 182.73). Participants with attentional deficits, who received rewards on a continuous schedule (A/C) , responded slower than comparisons on a continuous schedule (C/C) on the second trial block [$F(1, 32) = 4.01$, $p = .018$, $d = 1.05$], which was supported by a trend toward differences on the third trial block, $F(1, 32) = 3.94$, $p = .056$, $d = 1.06$ (Trial Block 2 A/C $M = 845.49$, SD = 326.25; C/C $M = 618.84$, SD = 136.89; Trial Block 3 A/C $M = 832.50$, SD = 305.11; C/C $M = 600.90$, SD = 157.22). No other simple effects approached significance (p's > .173) (see Fig. 1).

3.1.2. Reward phase reaction time variability

Analysis of variance of the standard deviation scores yielded an effect of group [$F(1, 32) = 13.85$, $p = .001$, $d = .96$], indicating that the responses of adults with an attentional deficit ($M = 378.14$, SD = 244.22) were more variable than comparisons ($M = 188.51$, SD = 163.74) across schedule conditions. The Group × Schedule × Trial Block interaction [$F(2, 31) = 1.72$, $p = .196$] failed to reach significance (see Fig. 1).

3.1.3. Extinction phase reaction time means

The same mixed design ANOVA for RT yielded a significant effect of group [$F(1, 32) = 11.05$, $p = .002$, $d = 1.20$], with the comparison group ($M = 635.64$, SD = 176.81) responding faster than the attention deficit group ($M = 990.41$, SD = 462.87) across schedule conditions. An analysis of the simple effects of the Group × Schedule × Trial Block interaction [$F(1, 32) = 3.98$, $p = .055$] revealed that the A/P group ($M = 1040.44$, SD = 344.43) was slower to respond than the C/P group ($M = 731.09$, SD = 184.39) only during Trial Block 4 (i.e., first ten trials of extinction), $F(1, 32) = 5.61$, $p = .024$, $d = 1.25$. The A/C group however, was slower to respond than the C/C group during both of the extinction trial blocks [Trial Block 4 $F(1,32) = 6.39$, $p = .017$, $d = 1.26$; Trial Block 5 $F(1,32) = 9.10$, $p = .005$, $d = 1.42$] (Trial Block 4 A/C $M = 868.69$, SD = 375.19, C/C $M = 557.55$, SD = 156.07; Trial

[1]Standardized mean differences were calculated using pooled standard deviations of the groups being compared (Olejnik & Algina, 2000). Cohen (1988) suggested the following terms for evaluating values of d: small effect = .2, medium effect = .5, large effect = .8.

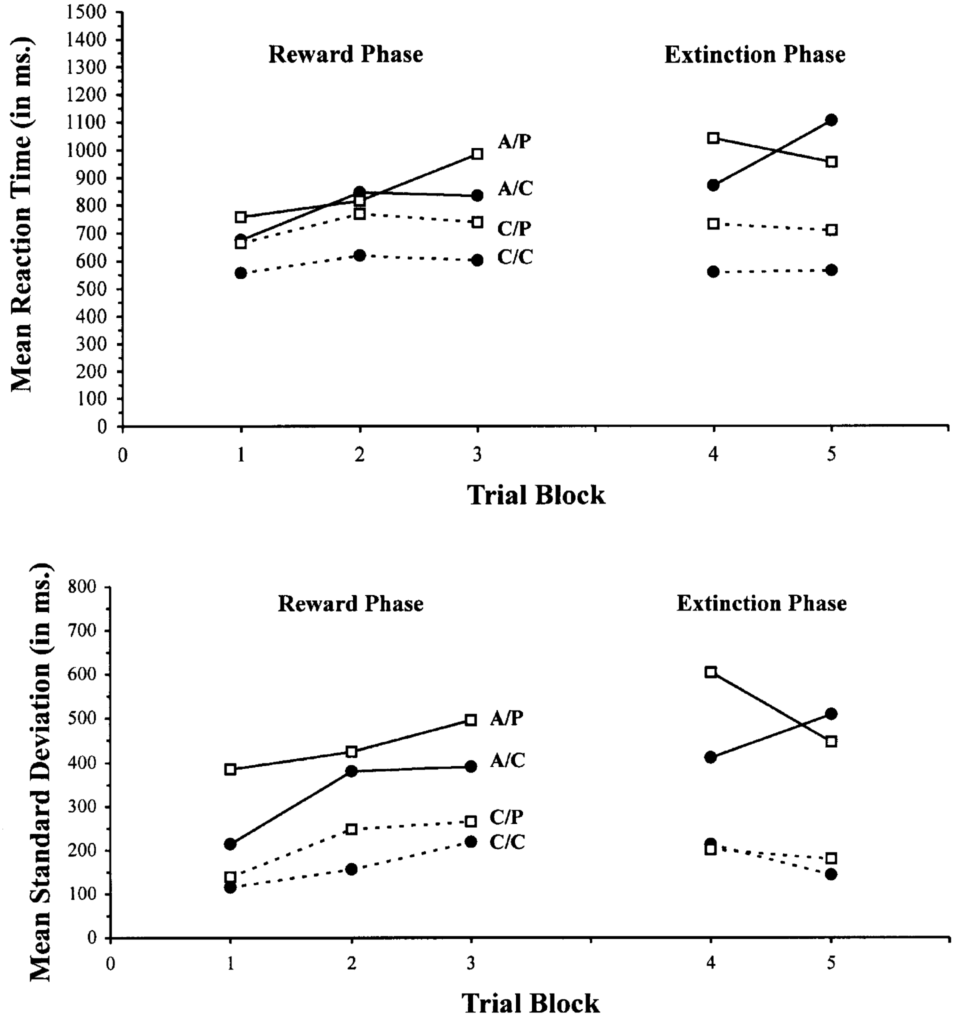

Fig. 1. Mean reaction times and variability of reaction times for adults with attentional deficits rewarded according to partial (A/P) and continuous (A/C) schedules and comparison adults rewarded according to partial (C/P) and continuous (C/C) schedules across reward and extinction trial blocks.

Block 5 A/C $M = 1101.63$, SD = 716.29, C/C $M = 562.30$, SD = 146.25). No other differences approached significance (p's > .20) (see Fig. 1).

3.1.4. Extinction phase reaction time variability

For the extinction data, an effect of group [$F(1, 32) = 8.67, p = .006, d = 1.06$] was yielded indicating that the responses of adults with attentional deficits ($M = 490.12$, SD = 460.99) were more variable than controls during extinction ($M = 183.63$, SD = 166.74). The simple effects of the Group × Schedule × Trial Block interaction [$F(1, 34) = 3.17$, $p = .084$] indicated that the responses of the A/P group ($M = 603.59$, SD = 350.59) were more variable than those of the C/P group ($M = 201.11$, SD = 103.43) on the fourth [$F(1, 32) = 6.23$, $p = .008$, $d = 1.99$] trial block. The responses of adults with attentional deficits, who had been rewarded according to a continuous schedule (A/C $M = 508.22$, SD = 578.92), were more variable than comparisons (C/C $M = 143.34$, SD = 136.81) on the final trial block of extinction (Trial Block 5), $F(1, 32) = 5.35$, $p = .027$, $d = 1.14$. No other effects approached significance (p's > .10) (see Fig. 1).

3.2. Force (frustration)

3.2.1. Reward phase force means

The force data were similarly analyzed and yielded an effect of Trial Block × Schedule [$F(2, 30) = 4.76$, $p = .016$]. Analysis of the simple effects of this interaction yielded a trend toward differences [$F(1, 17) = 4.15$, $p = .058$, $d = .29$] between the first ($M = 1409.61$, SD = 819.73) and third ($M = 1199.98$, SD = 821.90) trial blocks—indicating that the force exerted on the response button decreased somewhat over time only for those participants who were rewarded according to the continuous schedule. The Group × Schedule × Trial Block [$F(2, 30) = .38$, $p = .686$] interaction failed to yield significant effects (see Fig. 2).

3.2.2. Reward phase force variability

Similarly, the analysis of the simple effects of the Group × Schedule × Trial Block interaction [$F(2, 30) = 1.25$, $p = .300$] failed to yield differences between groups and schedules across the three reward phase trials blocks (see Fig. 2).

3.2.3. Extinction phase force means

Analysis of the Group × Schedule × Trial Block interaction yielded a significant effect, $F(1, 31) = 5.00$, $p = .033$. No differences among groups and schedules (e.g., A/C and A/P) for frustration were found. However, visual inspection and subsequent inferential analysis indicated the A/P group decreased the amount of pressure exerted on the response button over extinction trials [$F(1, 6) = 5.63$, $p = .055$, $d = .22$] (Trial Block 4 $M = 1565.33$, SD = 1263.21; Trial Block 5 $M = 1311.73$, SD = 999.78) (see Fig. 2).

3.2.4. Extinction phase force variability

The higher level Group × Schedule × Trial Block interaction [$F(1, 31) = 3.48$, $p = .072$] yielded differences between groups and schedules differentially across trial blocks. Simple effects analyses yielded trends toward differences. The A/P ($M = 541.60$, SD = 448.72) group was more variable than both the C/P group ($M = 331.20$, SD = 210.00) [$F(1, 31) = 2.94$, $p = .096$, $d = 1.00$] and the A/C group ($M = 295.78$, SD = 118.79) [$F(1, 31) = 3.64$, $p = .066$, $d = .69$] for the final extinction trial block (see Fig. 2).

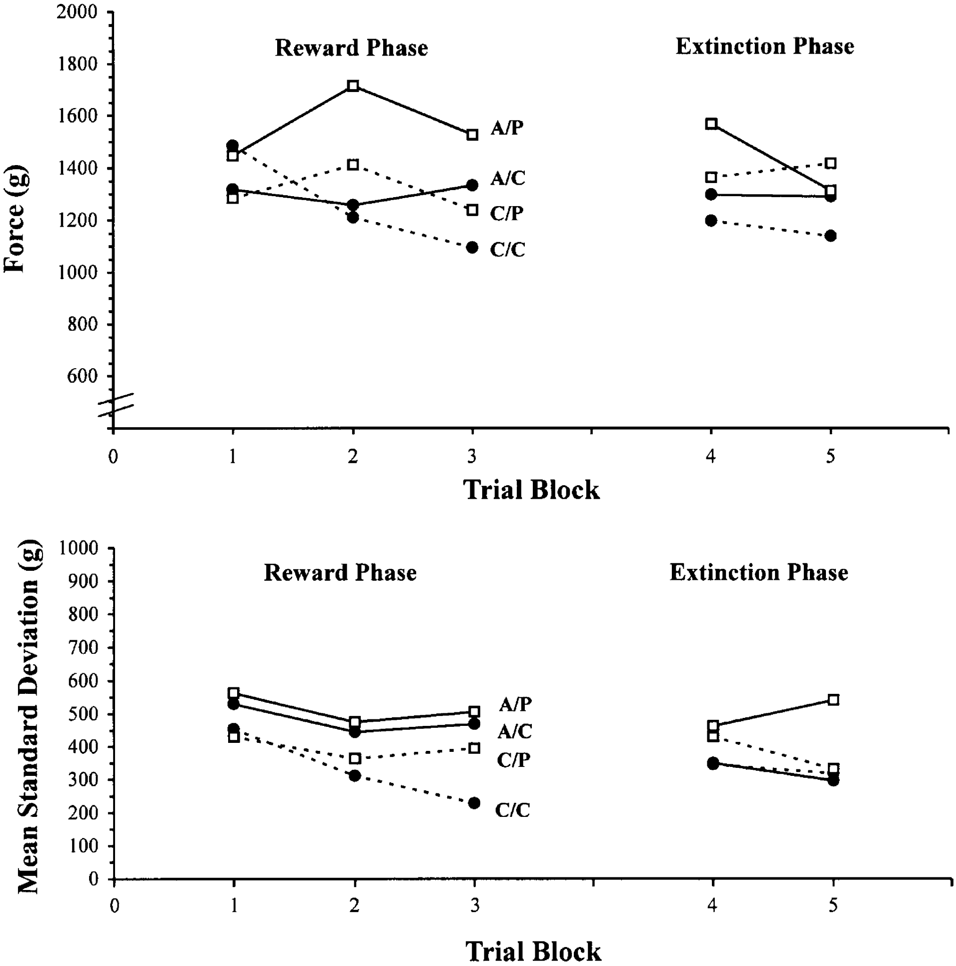

Fig. 2. Mean force and variability of force exerted on response button for adults with attentional deficits rewarded according to partial (A/P) and continuous (A/C) schedules and comparison adults rewarded according to partial (C/P) and continuous (C/C) schedules across reward and extinction trial blocks.

3.3. Analysis between reward and extinction phases

A secondary analysis was conducted in order to examine possible differences in responding from the last trial block of the Reward Phase (Trial Block 3) and the first trial block of extinction (Trial Block 4). This analysis yielded two trends toward differences. First, the reaction times of the adults in the A/P increased as extinction was introduced (Trial Block 3 $M = 984.48$, SD = 369.63; Trial Block 4 $M = 1040.44$, SD = 344.43) $F(1, 7) = 4.64$, $p = .065, d = .16$. Second, the force measure increased in variability for the C/C group between the final reward trial block

($M = 228.31$, SD = 124.21) and extinction ($M = 345.91$, SD = 195.19) $F(1, 9) = 3.66$, $p = .088, d = .74$). No other significant effects were found (p's $> .20$).

3.4. Movement and errors

Because of equipment malfunction, activity data were only available for 29 of the 36 participants (12 with attentional deficits and 17 comparisons). A main effect of group was yielded for the actometer data [$F(1, 25) = 12.94$, $p = .001, d = 1.57$] indicating that the adults with attentional deficits ($M = 28.33$, SD = 24.98) were more active during the experimental sessions than were comparisons ($M = 4.88$, SD = 7.89).

Commission error data were infrequent, because our CPT used only a target signal (i.e., participant was asked to respond to the letter A only), did not contain a warning signal (e.g., respond to the letter A *after* the letter X), and was presented in a trial format. For this reason, d' was not calculated. Errors of omission (i.e., not responding to the target stimulus in a timely manner) are reflected in the reaction time data. Analysis of the error data (i.e., omissions, commissions, delayed responses) failed to yield differences between groups, which aligns with prior research suggesting that error data on some rote tasks (e.g., math facts) are not sensitive to group differences at older ages, even though reaction time data retain sensitivity (Zentall, 1990).

4. Discussion

The purpose of this study was to examine reward sensitivity by assessing the effects of different schedules of reward on the attention and frustration levels of adults with attentional deficits during a sustained auditory attention task. Initially, we documented the validity of our task and participant selection procedures. That is even into adulthood, individuals with attentional deficits were more active and their attentional responses were slower and more variable than comparisons during the auditory CPT across conditions. These findings are similar to those reported elsewhere with children (see Conners, 1995) and adults (Barkley, Murphy, & Kwasknik, 1996) and address the call for more research assessing the overlap between children and adults with ADHD in behavior and learning (Faraone, 2000; Weyandt, Linterman, & Rice, 1995).

Based on Douglas and Parry (1994), we predicted that a continuous schedule of reward would normalize the performance of college-age adults with attentional deficits. That is, the adults in the attentional deficit group who were rewarded on a continuous schedule (A/C) would demonstrate equivalent attentional performance to comparisons rewarded on that same continuous schedule (C/C). Attention to task was operationally defined as time in ms from the onset of a target stimulus to the participant's response. We found that adults with attentional deficits performed similar to comparisons early in the task on the continuous schedule. However, the performance of the A/C group deteriorated across trial blocks (Fig. 1).

As well, we predicted that adults with attentional deficits would attend less to the task and experience more frustration than comparisons when rewarded on a partial schedule. Frustration was operationally defined as pressure (in g) exerted on a response pad and the variability of that response. As in prior work (e.g., Douglas & Parry, 1994; Wigal et al., 1998; Watson, 1969), this measure was designed to detect the behavioral manifestations of frustration (e.g., vigorously pressing a response pad) and not frustration manifested internally (e.g., physiological arousal). Findings were that the direction of both the attentional and frustration measures supported Douglas and Parry, but the differences just failed to reach statistical significance.

Also in line with Douglas and Parry (1994), we expected that during extinction the frustration level of the adults in the A/C group would be greater and more variable than that of comparisons. However, during extinction, the A/C and C/C groups did not differ in frustration (see Fig. 2). These specific findings differ from those documented elsewhere with elementary-age children with ADHD (e.g., Douglas & Parry, 1994; Wigal et al., 1998). Our failure to document this 'frustration' shift in the continuous reward condition suggests that the adults in our study did not accumulate a sufficient expectancy of reward to increase frustration during extinction. It may have been that the incentive value or quality of the reward was too small to achieve these effects (Douglas & Parry, 1994), or the college student participants may have learned to mediate or mask the frustration experienced by reduced or nonreward conditions.

We did, however, observe important effects on reaction time during the extinction trials of the continuous schedule. That is, the adults with attentional deficits assigned to a continuous schedule performed worse during extinction than comparisons on a similar continuous schedule. These effects did not appear to be due to task difficulty (lack of information/feedback), because the two groups demonstrated equivalent error performance on the CPT across all conditions. Parry and Douglas (1983) also ruled out feedback as a possible explanation for poor performance on a delayed reaction time task for hyperactive children (i.e., by adding a feedback condition to their experiment).

Overall, our results provide partial support for an arousal-based account of the responding of adults with attentional deficits across schedules of reward. As predicted by Douglas and Parry (1994), we found trends toward differences on the frustration measure during the reward phase for adults with attentional deficits rewarded on a partial schedule (A/P) group and comparisons (C/P). However, we also found differences between comparisons and adults with attentional deficits (A/C and C/C) during the continuous reward schedule and subsequent extinction phase on the attentional measure–something not predicted by Douglas and Parry.

Other researchers have also suggested that the behavior of children with ADHD is mediated by arousal. For example, Sergeant (Sergeant, 2000; Sergeant, Geurts, Huijbregts, Scheres, & Oosterlaan, 2003) applied the cognitive energetic model (Sanders, 1983) to explain the performance of children with ADHD. In this model, performance is determined by information processing (e.g., encoding, search, decision-making) and state factors or energetic pools (i.e., effort, arousal, activation). Zentall (1975) and Zentall and Zentall (1983) applied the arousal-based optimal stimulation theory more generally to explain the behavior of children with ADHD. Zentall suggested that children with ADHD require higher levels of stimulation than typical children to maintain attentional focus. The elevated activity level, generally associated with this group of children, is one attempt to increase stimulation (i.e., arousal). Based on this theory, children with ADHD may perform better on continuous reward schedules, because those schedules produce higher levels of stimulation. However, these same children will also habituate to stimulation faster than typical peers. In the present study, the continuous reward schedule normalized the early reaction time performance of the A/C group by functioning like added stimulation. The differences found later in the reward phase may have been due to the effects of habituation to the auditory CPT and the reward stimuli (for a discussion on the effects of habituation to task stimuli and the differential effects of added stimulation on CPT performance for children with attentional deficits see: Zentall, 1986; Zentall & Meyer, 1987).

These arousal-based theories (e.g., Douglas, 1985; Sergeant, 2000; Zentall, 1975) suggest that balance is important. Too much or too little arousal can negatively affect performance and behavior. In the current study, the responding of adults with attentional deficits in the continuous reward condition was similar to that of comparisons early in the reward condition, but differed later, after the adults with attentional deficits habituated to the reward stimuli. However, the frustration levels of those same adults did not differ from comparisons throughout the reward or extinction phases. In contrast, Douglas and Parry (1994) found differences between typical children and children with ADHD on a measure of frustration during extinction following continuous reward. Only on the partial schedule, where some frustration was observed, did the adults with attentional deficits perform more like the children in the Douglas and Parry study (1994). Taken together these results suggest that an optimal level of arousal is necessary to maintain persistent responding over time.

Future research examining the effects of reward schedules using a larger clinical sample of adults could find more robust effects, although the effect sizes we demonstrated were large for the attentional measure (reaction times). Two additional limitations of our sample should be noted. First, we did not differentiate among subtypes in our attention-deficit sample. Recent evidence suggests that ADHD is comprised of three distinct disorders (Gadow et al., 2004). The adults in our attention deficit group, who were initially identified based on the Brown ADD Scale, were most likely of the inattentive type. Our actometer data and self-report DSM-IV Hyperactivity Checklist scores indicated greater activity levels in the attention deficit group, but these activity levels failed to reach the current DSM-IV criteria for hyperactivity. However, the hyperactivity component of ADHD might be difficult to identify in adults, because these symptoms diminish more quickly than inattentive symptoms over the course of development (Biederman, Mick, & Faraone, 2000). Future researchers may wish to examine reward schedule across ADHD subtypes for both children and adults in order to examine possible differential effects. Second, our sample contained a disproportionate number of females, which differs from the samples of other researchers in this area (e.g., Douglas & Parry, 1994). Gaub and Carlson (1997) found that female children from community-based samples were less hyperactive and less aggressive than those children found in clinical samples, which may partially account for the smaller effect sizes on our frustration measure.

Notwithstanding, this work provides generality of prior research with children to adults. That is, on this auditory vigilance task we found that adults with attentional deficits were more active and demonstrated more overall problems in attention and persistence than comparison adults. More importantly these adults responded similarly to children with attentional deficits in their differential response to reward and stimulation. That is, continuous schedules may function like added stimulation, with similar habituation and decreased persistence on later trials. When rewards were withheld, performance deteriorated more rapidly than for comparisons. Additional research will be needed to determine whether frustration mediates this effect for adults, as it appears to for children (e.g., perhaps using more sensitive physiological measures).

These findings have both theoretical and applied implications. On a theoretical level we found that partial and continuous schedules of reward differentially affect the responses of adults with ADHD. These findings partially replicate those found with children and suggest that the delivery of rewards continues to affect this group of individuals throughout the lifespan. Applications of these findings, for example, could be in the development of instructional software that takes into account the variable patterns of responding and need for reward and stimulation. Similar applications could be derived to create optimal working environments or to provide vocational counseling for these individuals. This may be particularly important, given the evidence of the continuance of ADHD into adulthood, and the lack of social and vocational success experienced by adults with ADHD (Mannuzza et al., 1997).

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References

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

Amsel, A. (1958). The role of frustrative nonreward in noncontinuous reward situations. *Psychological Bulletin*, *55*, 102–119.

Barber, M. A., Milich, R., & Welsh, R. (1996). Effects of reinforcement schedule and task difficulty on the performance of attention deficit hyperactivity disordered and control boys. *Journal of Clinical Child Psychology*, *25*, 66–76.

Barkley, R. A. (1997). Behavioral inhibition, sustained attention, and executive functions: constructing a unifying theory of ADHD. *Psychological Bulletin*, *121*, 65–94.

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

Barkley, R. A., Murphy, K., & Kwasknik, D. (1996). Psychological adjustment and adaptive impairment in young adults with ADHD. *Journal of Attention Disorders*, *1*, 41–54.

Biederman, J., Mick, E., & Faraone, S. V. (2000). Age dependent decline of ADHD symptoms revisited: Impact of remission definition and symptom subtype. *American Journal of Psychiatry*, *148*, 564–577.

Biederman, J., Munir, K., & Knee, D. (1987). Conduct and oppositional disorder in clinically referred children with attention deficit disorder: a controlled family study. *Journal of the American Academy of Child and Adolescent Psychiatry*, *26*, 724–727.

Biederman, J., Munir, K., Knee, D., Armentano, M., Autor, S., Waternaux, C., & Tsuang, M. (1987). High rate of affective disorders in probands with attention deficit disorders and in their relatives: a controlled family study. *American Journal of Psychiatry*, *144*, 330–333.

Brown, T. R. (1996). *Brown Attention-Deficit Disorder Scales manual*. San Antonio, TX: The Psychological Corporation.

Cohen, J. (1988). *Statistical power analysis of the behavioral sciences* (2nd ed). New York: Academic Press.

Conners, C. K. (1995). *The continuous performance test*. Toronto: Multi-Health Systems.

Cunningham, S. J., & Knights, R. M. (1978). The performance of hyperactive and normal boys under differing reward and punishment schedules. *Journal of Pediatric Psychology*, *3*, 195–201.

Douglas, V. I. (1985). The response of ADD children to reinforcement: theoretical and clinical implications. In L. M. Bloomingdale (Ed.), *Attention deficit disorder: identification, course, and rationale* (pp. 49–68). New York: Spectrum.

Douglas, V. I., & Parry, P. A. (1983). Effects of reward on delayed reaction time task performance of hyperactive children. *Journal of Abnormal Child Psychology*, *11*, 313–326.

Douglas, V. I., & Parry, P. A. (1994). Effects of reward and nonreward on frustration and attention in attention deficit disorder. *Journal of Abnormal Child Psychology*, *22*, 281–302.

DuPaul, G., Anastopoulos, A. D., Shelton, T. L., Guevremont, D. C., & Metevia, L. (1992). Multimethod assessment of attention-deficit hyperactivity disorder: the diagnostic utility of clinic-based tests. *Journal of Clinical Child Psychology*, *21*, 294–402.

DuPaul, G. J., & Stoner, G. (1994). *ADHD in the schools: assessment and intervention strategies*. New York: Guilford Press.

Earle-Boyer, E. A., Serper, M. R., Davidson, M., & Harvey, P. D. (1991). Continuous performance tests in schizophrenic patients: stimulus and medication effects on performance. *Psychiatry Research*, *37*, 47–56.

Faraone, S. V. (2000). Attention deficit hyperactivity disorder in adults: implications for theories and diagnosis. *Current Directions in Psychological Science*, *9*(1), 33–36.

Freibergs, V., & Douglas, V. I. (1969). Concept learning in hyperactive and normal children. *Journal of Abnormal Psychology*, *74*, 388–395.

Gadow, K. D., Drabick, D. A. G., Loney, J., Sprafkin, J., Salisbury, H., Azizian, A., et al. (2004). Comparison of ADHD symptom subtypes as source-specific syndromes. *Journal of Child Psychology and Psychiatry*, *45*, 1135–1149.

Gaub, M., & Carlson, C. L. (1997). Gender differences in ADHD: a meta-analysis and critical review. *Journal of the American Academy of Child and Adolescent Psychiatry*, *36*, 1036–1045.

Gomez, R. L., Janowsky, D., Zetin, M., Huey, L., & Compton, P. L. (1981). Adult psychiatric diagnosis and symptoms compatible with the hyperactive syndrome: a retrospective study. *Journal of Clinical Psychiatry*, *42*, 389–394.

Johansen, E. B., Aase, H., Meyer, A., & Sagvolden, T. (2002). Attention-deficit/hyperactivity disorder (ADHD) behaviour explained by dysfunctioning reinforcement and extinction processes. *Behavioural Brain Research*, *130*, 37–45.

Kaufman, N. L., Kaufman, A. S., & Newman, E. J. (2001). Review of Brown attention-deficit disorder scales. In B. S. Plake, & J. C. Impara (Eds.), *Mental measurement yearbook*, (14th ed.). Lincoln, NE: Buros Institute.

Keppel, G. (1991). *Design & analysis: a researcher's handbook* (3rd ed.). Englewood Cliffs, NJ: Prentice-Hall.

Madan-Swain, A., & Zentall, S. S. (1990). Behavioral comparisons of liked and disliked hyperactive children in play contexts and the behavioral accommodations by their classmates. *Journal of Consulting and Clinical Psychology*, *58*, 197–209.

Mannuzza, S., Klein, R. G., Bessler, A., Malloy, P., & Hynes, M. E. (1997). Educational and occupational outcome of hyperactive boys grown up. *Journal of the American Academy of Adolescent Psychiatry*, *36*, 1222–1227.

Mattes, J. A., Boswell, L., & Oliver, H. (1984). Methylphenidate effects on symptoms of attention deficit disorder in adults. *Archives of General Psychiatry*, *41*, 1059–1063.

Muniz, L. (1996). Test review: Brown attention-deficit disorder scales and Brown diagnostic forms. *Diagnostique*, *22*, 63–74.

Olejnik, S., & Algina, J. (2000). Measures of effect size for comparative studies: applications, interpretations, and limitations. *Contemporary Educational Psychology*, *25*, 241–286.

Parry, P. A., & Douglas, V. I. (1983). Effects of reinforcement on concept identification in hyperactive children. *Journal of Abnormal Child Psychology*, *11*, 327–340.

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

Rapport, M. D., Tucker, S. B., DuPaul, G. J., Merlo, M., & Stoner, G. (1986). Hyperactivity and frustration: the influence of control over size of rewards in delaying gratification. *Journal of Abnormal Child Psychology*, *14*, 191–204.

Sagvolden, T., & Sergeant, J. A. (1998). Attention deficit/hyperactivity disorder—from brain dysfunctions to behaviour. *Behavioural Brain Research*, *94*, 1–10.

Sanders, A. F. (1983). Towards a model of stress and performance. *Acta Psychologica*, *53*, 61–97.

Sergeant, J. (2000). The cognitive-energetic model: an empirical approach to attention-deficit hyperactivity disorder. *Neuroscience and Biobehavioral Reviews*, *24*, 7–12.

Sergeant, J. A., Geurts, H., Huijbregts, S., Scheres, A., & Oosterlaan, J. (2003). The top and bottom of ADHD: a neurological perspective. *Neuroscience and Biobehavioral Reviews*, *27*, 583–592.

Shekim, W. O., Asarnow, R. F., Hess, E., Zaucha, K., & Wheeler, N. (1990). A clinical and demographic profile of adults with attention deficit hyperactivity disorder, residual state. *Comprehensive Psychiatry*, *31*, 416–425.

Sonuga-Burke, E. J. S. (2002). Psychological heterogeneity in AD/HD—a dual pathway model of behavior and cognition. *Behavioural and Brain Research*, *130*, 29–36.

Sonuga-Burke, E. J. S. (2003). The dual pathway model of AD/HD: an elaboration of neuro-developmental characteristics. *Neuroscience and Biobehavioral Reviews*, *27*, 593–604.

Tartar, R. E., McBride, H., Buonpane, N., & Schneider, D. U. (1977). Differentiation of alcoholics: childhood history of minimal brain dysfunction, family history, and drinking pattern. *Archives of General Psychiatry*, *34*, 761–768.

Tripp, G., & Alsop, B. (2001). Sensitivity to reward delay in children with attention deficit hyperactivity disorder (ADHD). *Journal of Child Psychology and Psychiatry*, *42*, 691–698.

Watson, P. (1969). Reward schedule, response measure, and attentional deficiency: a reanalysis. *Psychonomic Science*, *16*, 70–72.

Wender, P. H., Reimherr, F. W., Wood, D. R., & Ward, M. (1985). A controlled study of methylphenidate in the treatment of attention deficit disorder. *American Journal of Psychiatry*, *142*, 547–552.

Weyandt, L. L., Linterman, I., & Rice, J. A. (1995). Reported prevalence of attentional difficulties in a general sample of college students. *Journal of Psychopathology and Behavioral Assessment*, *17*, 293–304.

Wigal, T., Swanson, J. M., Douglas, V., Wigal, S. B., Wippler, C. M., & Cavoto, K. F. (1998). Effects of reinforcement on facial responsivity and persistence in children with attention-deficit hyperactivity disorder. *Behavior Modification*, *22*, 143–166.

Zentall, S. S. (1975). Optimal stimulation as a theoretical basis of hyperactivity. *American Journal of Orthopsychiatry*, *45*, 549–563.

Zentall, S. S. (1986). Effects of color stimulation on performance and activity of hyperactive and nonhyperactive children. *Journal of Educational Psychology*, *78*, 159–165.

Zentall, S. S. (1989). Attentional cuing in spelling tasks for hyperactive and comparison regular classroom children. *The Journal of Special Education*, *23*, 83–93.

Zentall, S. S. (1990). Fact-retrieval automatization and math problem solving; leaning disabled, attention disordered, and normal adolescents. *Journal of Educational Psychology*, *82*, 856–865.

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

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

Zentall, S. S., & Zentall, T. R. (1983). Optimal stimulation: a model of disordered activity and performance in normal and deviant children. *Psychological Bulletin*, *94*, 446–471.