THE ROLE AND REMEDIATION OF ATTENTION DEFICITS IN PERFORMANCE OF MATHEMATICS FACTS BY CHILDREN WITH ADHD

DISSERTATION

Presented in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy in the Graduate School of The Ohio State University:

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Attention-Deficit/Hyperactivity Disorder (ADHD) is a disorder characterized by the occurrence of behavior patterns that display abnormal levels of attention, impulsivity and hyperactivity. Parents and teachers commonly associate attention deficits with underachievement in children with ADHD. The purposes of this study were (a) to provide an assessment method to investigate attention in children with ADHD, (b) to evaluate the impact of an observing response to focus attention on relevant stimuli on the accuracy and rate of responding to mathematics facts, and (c) to examine the role of delay aversion on responding. Participants were repeatedly exposed to four conditions. During Observing conditions, discriminative responding to a relevant (Relevant Observing) or irrelevant (Irrelevant Observing) stimulus was required before solution of the mathematics problem. During control conditions, responses to the mathematics facts could occur immediately after problem presentation (No Wait) or after a short delay (Wait). The results indicate, first, that rates of correct responding on mathematics facts increased for all participants across sessions in all conditions. Second, the observing response requirement to enhance control by the relevant stimulus did not produce consistent differences in rate and accuracy when compared to the other conditions. Finally, Wait and No Wait conditions did not produce consistent differences in responding for children with or without ADHD, suggesting that delay aversion did not
affect performance. Likely explanations for these results are discussed along with implications for the design of future interventions for children with ADHD.
To my beloved husband, Manoel
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CHAPTER 1

INTRODUCTION

According to the American Psychiatric Association (2000), 3% to 7% of the childhood population has attention deficit hyperactive disorder (ADHD). ADHD represents one of the most common reasons children are referred for behavior problems to medical and mental health practitioners in the United States (Barkley, 2006). Up to 80% of children diagnosed with ADHD have been found to exhibit learning and/or achievement problems (Cantwell & Baker, 1991; Frick et al., 1991; Lambert & Sandoval, 1980) and more than 40% receive special education services (Stoner, Carey, Ikeda, & Shinn, 1994). Given the association between ADHD and academic underachievement, many researchers have tried to identify the underlying causes of the disorder. Some assert that academic underachievement is presumably due to the exhibition of the core symptoms of ADHD in classroom settings (DuPaul & Barkley, 1990; Silver, 1990). For example, high levels of activity could divert attention from instruction. Others have argued that both ADHD and learning difficulties are caused by a third variable, such as nonspecific neurological impairments (Keogh, 1971) or environmental issues (Hinshaw, 1992). Despite the interesting research and discussions these hypotheses have generated,
conclusions about causality are premature. Nevertheless, it is clear that many children with ADHD have academic deficits that must be addressed.

Increasing attention to instruction is one of the most logical ways to increase performance. However, the relation between attention and performance in children with ADHD is still unclear. Several factors contribute to the problem of identifying attending patterns and how they affect performance. The main problem relates to the measurement of attention. Attention can be measured physiologically, topographically or functionally. Physiological measures involve, for example, the assessment of eye movements and brain functions. Topographical measures involve observations of specific forms of behaviors that are selected by the investigator. For example, gaze orientation toward an academic stimulus (or other presumed indications of being “on task”) is usually the kind of behavior assessed to record the occurrence of attention. Topographical measures are more easily obtained than physiological measures, but they are typically used to assess behaviors related to the phenomena and not the phenomena itself. In other words, contact with the stimulus is a necessary but not a sufficient condition to assert that the stimulus is affecting the person’s behavior. Functional measures are also inferential in that attention is assumed when subsequent behavior is affected by the stimuli that are being presented. For example, attention to the red light is assumed when the driver stops the car in its presence. Nonetheless, functional measures have the advantage of focusing on the product of interest (i.e., performance) among the variety of processes that are involved in the phenomena of attention. Unfortunately, most studies involving this disorder have used topographical measures of attention.

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Ford, Poe and Cox (1993), for example, investigated specific types of software packages on topographical measures of behaviors presumed to interfere with attending (e.g., fidgeting, getting out of seat, talking to a neighbor). Performance measures were not assessed. The results indicated that the use of a game format as opposed to a tutorial without excessive animation was the type of package that produced the lowest levels of nonattending. Sherman and Anderson (1980) investigated the efficacy of using performance feedback on reducing the current high levels of behaviors that are incompatible with attending. The authors concluded that children can control their behavior and increase on-task production under appropriate conditions. Specifically, the authors reported that nonattending behaviors were substantially reduced when children were informed about their inattention. Craig and Holland (1970) investigated the efficacy of immediate tangible reinforcement on attending. Attending was recorded if the child was seated and if his eyes were directly oriented toward the relevant teaching stimulus for the full time period during which he was being observed. The use of a reinforcement procedure increased visual attending, suggesting that it is an operant behavior that can be modified.

Although informative, this type of research presents significant limitations. The occurrence of attention is inferred based only on antecedent behaviors that are usually correlated with attention (e.g., note taking during class) or incompatible with attention (talking with friends during instruction). When teachers and parents worry about attention, they are more frequently concerned with poor performance outcomes that are assumed to come from a deficient attentional process. In order to investigate interventions that
increase attention leading to responding under stimulus control, functional measures seem more appropriate. Different strategies have been used (primarily in basic research) to investigate attention using functional measures while controlling for other variables that could affect this process (e.g., failure to sense the stimulus, motivation etc). One of these strategies uses a procedural modification that allows an additional response to be emitted by the participant. This response is called the observing response. Attending to the stimulus is assumed when the observing response is emitted and responding on the primary reinforcement key is under appropriate stimulus control. In this procedure, an overt response produces the discriminative stimuli without affecting the rate of reinforcement. Responses on the observing key only assure contact with the stimulus while measures of appropriate responding to the target task indicate the impact of observed and unobserved stimuli on responding.

In another strategy, a matching to sample (MTS) procedure is used not only to assure contact with the stimulus but to assure contact with the most relevant properties of the sample stimulus. This procedure was used, for example, by Walpole, Roscoe and Dube (2007). Children with autism were exposed to two different types of matching to sample tasks. In non-overlapping trials, sample and comparisons differed for all three of the letters that formed each word (e.g., cat, lid, and bug). In overlapping trials, sample and comparisons differed according to only one of the three letters of the words (e.g., cat, can, and car). Responding during overlapping trials showed that behavior was under restricted stimulus control (the first letter of each word of the sample and the comparisons). In order to remedy this problem, a differential observing response (DOR)
was used prior to the presentation of the overlapping trials. DOR is a procedural modification that may improve discrimination by demanding a differential response in the presence of the sample stimuli. DOR procedures control observing and verify discrimination of critical features of the stimuli. In Walpole et al., the DOR was used in the context of a matching to sample task in which only the letters that differed among the overlapping words were compared (e.g., t, n, r). The introduction of the DOR was effective in increasing accurate responding during the overlapping trials even after the DOR requirements were removed. The authors concluded that the use of the DOR was effective in broadening the range of observing behavior during stimuli presentation.

The Walpole et al. (2007) study offers an example of the use of a functional measure of attention, while attention to the target stimulus is enhanced by the requirement of an observing response to the sample. Discriminative control by the sample is assessed by responses to the MTS task. Informed by these results, it was determined that inaccurate responses were not due to lack of contact with the discriminative stimulus, but to faulty stimulus control. Subsequently, faulty stimulus control was addressed by the use of a DOR that assured appropriate control by the relevant stimuli (the entire word). Children with ADHD also may benefit from this methodology. Research could examine the extent to which first establishing control by the relevant stimulus would impact the performance of children with ADHD on academic tasks. DOR procedures might help to improve academic performance of children with ADHD to the extent that their performance deficits are attributable in part to failure to attend and respond to relevant stimuli.
Although attention deficits are highly correlated with underachievement in children with ADHD, some researchers have argued that the central feature of ADHD may be an impairment in behavioral inhibition rather than a deficit in attention per se (Barkley, 2006; Nigg, 2001). Sonuga-Barke, Houlberg, and Hall (1994) have argued that inattention and overactivity as well as impulsivity can be seen as expressions of delay aversion. Although formally distinct clinical manifestations, they can be viewed as functionally equivalent with the underlying function being escape from, avoidance of, or, at the least, reduction of perceived delay. That is, inattention and overactivity in children with ADHD could represent attempts to reduce the perceived (but not the actual) length of time passing.

For example, it has been shown that when an individual’s attention is directed toward aspects of a situation that reduce awareness of the passage of time (nontemporal stimuli) and away from aspects that emphasize it (temporal stimuli), the length of that time period seems shorter. Solanto et al. (2001) pointed out that, subjectively, delay can be reduced effectively under fixed delay conditions by maximizing attention to nontemporal stimulation, fidgeting, or otherwise eliciting stimulation from the environment. “Patterns of attention and action that would serve to reduce the subjective experience of time in passing correspond closely with the types of irregular activity and sustained attention problems seen as characterizing the attentional style associated with ADHD” (pp. 225-226). If these theories are correct, interventions to increase academic responding should focus on reducing delay aversion rather than on directly increasing attention. There has been little research addressing this issue, however.
Purposes of the study

There were three main purposes for the current study. The first one was to provide an assessment method to investigate attention in children with ADHD. The second one was to evaluate the impact of an observing response to focus attention on relevant stimuli on the accuracy and rate of responding to mathematics facts. The third one was to examine the role of delay aversion on responding.

Research Questions

The specific research questions addressed in this study were: (a) Will requiring an observing response to enhance control by relevant stimuli before answering a problem increase the rate and percentage of accurate responding to mathematics facts? (b) Does delay aversion impact the rate and percentage of accurate responding to mathematics facts? (c) What conditions will be most preferred by the participant?
Diagnosing ADHD

Attention-Deficit/Hyperactivity Disorder (ADHD) is a disorder characterized by the occurrence of significant behavior patterns that display abnormal levels of attention, impulsivity and hyperactivity. ADHD represents one of the most common reasons children in the United States are referred for behavior problems to medical and mental health practitioners (Barkley, 2006). Although there is no commonly accepted objective method for diagnosing ADHD, the diagnostic criteria are specified in the Diagnostic and Statistical Manual of Disorders (DSM-IV) (American Psychiatric Association, 2000).

The DSM-IV requires that some hyperactive-impulsive or inattentive symptoms are apparent prior to the age of 7 years, the symptoms are present in two or more settings, and there is clear evidence of significant impairment in academic, social, or occupational functioning. Additionally, a diagnosis requires that six or more of the following symptoms of inattention or hyperactivity-impulsivity have persisted for at least 6 months to a degree that is maladaptive with developmental level:

Inattention
(a) often fails to give close attention to details or makes careless mistakes in schoolwork, work, or other activities
(b) often has difficulty sustaining attention in tasks or play activities
(c) often does not seem to listen when spoken to directly
(d) often does not follow through on instructions and fails to finish schoolwork, chores, or duties in the workplace (not due to oppositional behavior or failure to understand instructions)
(e) often has difficulty organizing tasks and activities
(f) often avoids, dislikes, or is reluctant to engage in tasks that require sustained mental effort (such as schoolwork or homework)
(g) often loses things necessary for tasks or activities (e.g., toys, school assignments, pencils, books, or tools)
(h) is often easily distracted by extraneous stimuli
(i) is often forgetful in daily activities

Hyperactivity-Impulsivity

Hyperactivity

(a) often fidgets with hands or feet or squirms in seat
(b) often leaves seat in classroom or in other situations in which remaining seated is expected
(c) often runs about or climbs excessively in situations in which it is inappropriate (in adolescents or adults, may be limited to subjective feelings of restlessness)
(d) often has difficulty playing or engaging in leisure activities quietly
(e) is often “on the go” or often acts as if “driven by a motor”
(f) often talks excessively

Impulsivity

(g) often blurts out answers before questions have been completed
(h) often has difficulty awaiting turn
(i) often interrupts or intrudes on others (e.g., conversations or games)


Typically, problems with attention and the other related symptoms of ADHD are assessed by diagnostic interviews, behavior rating scales, and medical examinations (Pelham et al., 2000). However, assessments of hyperactivity, inattention, and impulsivity are often subjective, and concerns have been expressed about their reliability and validity (e.g., Conners, 2000; Reid & Magg, 1994). Conners points out that there is often disagreement among caregivers about the extent to which particular symptoms are present. In addition, parent and teacher ratings frequently yield different results than direct behavioral observations (Barkley, 1991). Other limitations are that scales (a) may not have sufficient sensitivity and utility for treatment development and monitoring (Angello et al., 2003); (b) are subject to error variance by factors that affect the informant rather than the subject of the ratings (Barkley, 1991); (c) do not deal with situational and temporal fluctuations that may distort the results; and (d) use items that do not necessarily represent the construct, but simply covary with it. This last limitation relates to
topographical measures which involve observations of specific forms of behaviors selected by the investigator. These behaviors usually covary with the phenomena; however, they are not the phenomena itself. In other words, contact with the stimulus is a necessary but not a sufficient condition to assert that the stimulus is affecting the person’s behavior.

Another form of assessment of ADHD symptoms is direct observation in the natural environment. A clear advantage of this method in comparison to rating scales is the fact that it accommodates situational and temporal influences on behavior. Measurement is conducted repeatedly in different environments and situations. In addition, behavioral observations involve the use of operationally defined categories of behavior that are recorded in the natural environment. Despite their advantages, observation methods also present limitations. First, they can be expensive due to the need for trained professionals and the time involved in data collection. Second, there is the potential for reactivity effects. Finally, the phenomena of interest might be difficult to observe directly.

Laboratory assessment methods (LM) are also used to diagnose ADHD. According to Barkley (1991), LMs are very useful in testing theoretical predictions, “particularly those requiring precise control over extraneous variables and precise definition and measurement of the behavior of interest” (p.151). However, in order to predict children’s behavior in their natural setting, Barkley argues that the LM must go through a process of ecological validation. For example, Gordon (1983) developed, norm-referenced, and commercially marketed a small, portable, computerized device that
administered two tests believed to be sensitive to the deficits of children with ADHD. However, the instrument was subsequently shown to be insensitive to stimulant medication effects (i.e., ecologically invalid) and was eventually deemphasized as useful in the diagnosis of ADHD. Another example is continuous performance tests, which have proven insensitive to the attentional deficits of children with ADHD.

Because no one type of diagnostic approach has proven to be completely satisfactory, some researchers defend the use of a behavioral assessment approach that incorporates parent and teacher interviews, rating scales, direct observation of behavior, and academic performance data to address both the diagnostic and evaluative goals of the assessment process (e.g., DuPaul, & Stoner, 1994). This proposed solution is problematic if the confluence of limitations with each of these assessments is taken into account. These are the standard assessment approaches that are available to investigate ADHD and to assess the relationship of ADHD and other behaviors of interest (e.g., academic performance, rule following). Given the limitations of the procedures associated with these approaches, the need for more appropriate procedures to investigate ADHD more reliably and effectively, especially outside the medical scope, is imperative.

ADHD and Performance

Up to 80% of children diagnosed with ADHD have been found to exhibit learning and/or achievement problems (Cantwell & Baker, 1991; Frick et al., 1991; Lambert & Sandoval, 1980). Because almost all children diagnosed with ADHD are doing poorly at school, DuPaul and Stoner (1994) advise that the evaluation of ADHD must not be
directed just toward behavior control, but should also include measures of academic performance. Silver (1990) suggests that the primary behaviors characteristic of children with ADHD (i.e., inattention, impulsivity, and overactivity) disrupt the children’s ability to acquire academic skills and/or to demonstrate their knowledge in a consistent fashion. Often, diverted attention from instruction is seen as a major factor that minimizes the acquisition and performance of academic skills. Regardless, the relationship between ADHD and achievement is not clearly understood.

Ferritor, Buckholdt, Hamblin, and Smith (1972) investigated the relation between attending behavior and the number of problems correct on arithmetic drills in children with ADHD. A 10 s time sampling procedure was used to record data for 14 third-graders from an inner city school. Attending behaviors were recorded when a child was looking at or writing his test paper, counting aloud on his fingers, passing out papers, etc. During conditions in which reinforcement was contingent exclusively upon attending behavior, an increase in attending was observed, but there were no changes in performance. When reinforcement was contingent exclusively upon arithmetic performance, the opposite was observed. Finally, when reinforcement was contingent upon both attending and performance, both behaviors increased. These results suggest that contingencies that increase attending behavior, as defined by the authors, do not necessarily increase student performance.

Ota and DuPaul (2002) also investigated the relationship between attending and performance. They examined the effects of the use of software in a game format on the mathematics performance of children with ADHD. The results showed that instruction
provided via computer games led to increases in active engagement relative to independent seatwork conditions. However, increased active engagement led to only modest increases in academic performance (number of mathematics problems correct per minute).

There have been few direct investigations of the relation between attention deficits and performance (as described above). DuPaul and Eckert (1997) pointed out that, although the target behaviors are often achievement-oriented, the focus of the studies is on behaviors that “look like” attention or some form of behavior control. As a result, suggestions about improvement in performance are only speculative. Consequently, it is unclear to what degree the interventions under investigation enhance academic achievement of students with ADHD.

Purdie, Hattie, and Carroll (2002) examined 74 studies in which there had been an intervention that aimed to improve the behavioral, cognitive, and/or social functioning of individuals with ADHD. They found that behavioral outcomes were stronger than educational outcomes. In addition, off-task behaviors were the most common targets for behavioral interventions.

Research on discrimination training has produced better outcomes in increasing attention levels and performance than research on the effects of attention on performance and off-task behaviors (e.g., Davison & Jenkins, 1985, DePaulo, DeWald, & Yarczower, 1977; Madden & Perone, 1999). These studies suggest that discrimination training may increase attention to the stimuli correlated with contingencies that lead to improved performance. On the other hand, similar to research on attending and academic
performance, research on discrimination training has shown that the mere presence of the
discriminative stimulus might not be enough to enhance sensitivity to experimental
conditions (Jenkins & Harrison, 1960; Madden & Perone, 1999). Vigilance to stimuli
 correlated with each schedule is required in many cases. Madden and Perone, for
example, showed that when participants were required to correctly identify the color
correlated with the source schedule, responding was more sensitive than when the
discriminative stimuli were available, but no contingencies regarding its use were in
place. One possible interpretation of their results is that attention may be a selective
process comprising a distinct functional category that has important effects on other
behaviors.

According to DePaulo et al. (1977), discrimination training might enhance
stimulus control because it sets the occasion for the occurrence of discriminative
responding. Specifically, it increases attention to critical differences between positive and
negative stimuli. Similarly, Dinsmoor (1985) added that it is a reasonable suggestion that
people are more likely to be influenced by variations in some aspect of the stimulus if the
person is attending to the stimulus. In fact, Dinsmoor pointed out that in many studies
observing responses increased under the same conditions as those that produced an
increase in stimulus control and vice-versa. Observing responses are a procedural artifact
to study attending. Observing responses are defined as responses to an additional key that
gives access to the discriminative stimuli without affecting the schedule of reinforcement
in place.
In sum, the relation between attention and academic performance is not clearly understood. Whereas some studies suggest that they are completely unrelated, others suggest that under appropriate training and conditions they have a stronger relation. In addition, given that some studies defined attending topographically, it is unclear if the increases in attention were increases in behaviors that “look like” attending rather than behaviors that share a functional relationship with the phenomena of attending. If this is the case, caution is necessary in interpreting results of studies involving attending and its relationship with performance. Future studies are necessary in order to better understand the relation between attention and performance. These studies must assess both the behavioral and the performance aspects of this relation by using an objective and functional measure of attending.

Attending

Conceptualization

Deficits in attention are seen by many as “the major symptom construct that forms the essential nature of this disorder” (Barkley, 2006, p. 77). In fact, it is the dimension of attention that inspired the name of the disorder. In everyday vocabulary, differences in behavior among persons under the same environmental conditions are often discussed in terms of attending. For example, differences in performance on tests are attributed to different levels of attending during class. The term attention is usually invoked when there is a failure of the environmental stimuli to guide behavior even when they are apparently adequate to do so. However, means of defining attention often vary.
According to Donahoe and Palmer (2004), this is not surprising because “there is not one phenomenon of attention” (p. 152). In other words, under the heading of attention a diverse and varying assortment of biobehavioral processes are described. When we say that one child did better on a test than the other because the former paid more attention, many different processes might explain this outcome. Behavior may have failed to occur because of lack of control by the specific stimulus, because the discriminative stimulus was not sensed by the organism, or because the biobehavioral processes evoked by other stimuli interfered with the control of behavior by the discriminative stimuli. Although appropriate, grouping all these different phenomena under the label of “attention” might lead to theoretical incoherence. That is, the term that is initially used as a “summary” of different phenomena becomes the explanation for them. Unfortunately, using lack of attention as an explanation for the behavior of children with ADHD is a common practice. Identifying the specific processes that contribute to the lack of stimulus control on these children would be much more beneficial.

In general, lack of stimulus control occurs for a variety of reasons. First, there might be a failure to establish discriminative control by the relevant stimuli. Cooper, Heron, and Heward (2007) stated that a behavior is under stimulus control when it is “emitted more often in the presence of the discriminative stimulus than during its absence” (p. 299). Behavior comes under stimulus control when a response is emitted and reinforced in the presence of one stimulus (i.e., $S^+$ or $S^D$) but is not reinforced when emitted in the presence of another stimulus (i.e. $S^-$ or $S^\Delta$). The stimulus present when reinforcement occurs comes to signal the availability of reinforcement and the behavior
becomes more likely to occur in the presence of this stimulus. In some cases, this relation might be jeopardized when control is inadvertently established by irrelevant stimuli or specific properties of the discriminative stimulus.

Second, lack of stimulus control might occur due to a failure to sense the discriminative stimulus. For example, the organism may engage in behavior that impedes sensing the discriminative stimulus. Failure to sense the stimulus is frequently cited as the reason for inappropriate responding in children with ADHD. It is not surprising, then, that attending in many studies is defined as appropriate looking which functions as a mechanism to collect information from the environment. Third, sometimes the acquisition of new stimulus control is blocked by the original controlling relation. In other words, regardless of the change in the contingencies, new stimulus control is not established or takes longer. Finally, it might be the case that stimuli do not exert control due to a change in the context of their presentation. Sometimes, in the process of establishing stimulus control, irrelevant stimuli also acquire control over behavior and in their absence, behavior is not evoked.

Unfortunately, due to the different conceptualizations and methodologies used to investigate the attention phenomena, our knowledge about the extent to which the inappropriate behaviors of children with ADHD are actually driven by inappropriate/deficient stimulus control or other variables is very limited. One must investigate if or how each one of these processes interferes with these children’s behaviors. Clarification of these relations could have numerous benefits in advancing the conceptualization of the disorder and in informing effective interventions.
Methodological Issues

Studying attention can be very challenging because some of the processes involved when we talk about attention may be observed at the behavioral level, but others require observation at the microbehavioral and physiological levels (Donahoe & Palmer, 2004). Craig and Holland (1970), for example, defined attending as appropriate looking that functioned as a mechanism to collect information from the environment. In their study, "Attending’ was recorded if the child was seated and if his/her eyes were directly oriented toward the relevant teaching stimulus for the full time period during which he/she was being observed” (p. 98). The main challenge with this definition is that neither directionality or the absence of competing responses guarantee that the target stimulus is having any impact on the student or, more specifically, would exert control over his/her future responding. For example, someone might be staring at the TV and still be unable to report what just occurred even when the ability to report is in the repertoire and the individual was observed to be ‘attending.’

Basic researchers have used an alternative approach to study attending. Their methodology has proven to be effective and practical in the study of attention (Bowe & Dinsmoor, 1983; Case & Fantino, 1981; Case, Fantino, & Wixted, 1985; Dardano, 1965; DePaulo et al., 1977; Dinsmoor, 1985; Fantino & Case, 1983; Gaynor & Shull, 2002; Heinemann, Chase & Mandell, 1968; Lieberman, 1972; Nevin, Davison, & Shahan, 2005; Perone & Kaminski, 1992; Shahan, 2002; Shahan, Magee, & Dobberstein, 2003; Shahan & Podlesnik, 2005; Wilton & Clements, 1971; Wycoff, 1952). Attending has been examined by using mixed/multiple schedules of reinforcement in which the
transition from one schedule to another is dependent on the occurrence of observing responses. Attending to the stimulus is assumed when the observing response is emitted, and responding on the primary reinforcement key is under appropriate stimulus control. According to Dinsmoor (1985), the working hypothesis is that observing and attending are responses that obey similar principles; however, the processes involved in attention are “presumably events that occur in the neural tissue” (p. 365) and are therefore not readily accessible to observation. Therefore, artificial observing responses that occur earlier in the chain and are passive of direct measurement should be used as an alternative. Nevin et al. (2005) make clear that although attending is a hypothetical construct, it refers to physically real but unmeasured activities that have properties similar to measured overt responding. In fact, Skinner (1953) defined attention as the control exerted by a discriminative stimulus that is inferred by the relation between a response and a discriminative stimulus. This relation, as in any other form of overt responding, is controlled by environmental variables such as motivation and dimensions of reinforcement and punishment.

In basic studies examining attending, observing is defined as overt responding that brings sensory receptors into contact with discriminative stimuli associated with the conditions of availability of primary reinforcement, but which does not alter the availability of primary reinforcement (Wyckoff, 1952, 1969). The discriminative stimulus that is positively correlated with reinforced responding is the S+, and the stimulus that is negatively correlated with reinforcement (extinction) is the S-. In sum, basic researchers measure contact between the organism and the relevant stimuli in the situation. Studies
using this methodology have been successful in objectively measuring the behaviors of interest and in elucidating some of the variables that impact observing behaviors.

Previous research

Observing response procedure

Observing responses that produce discriminative cues are readily learned by humans and other animals. However, the variables that maintain such behavior and possibly attending are not well known. For this reason, experiments on observing have addressed the question of why observing responses are maintained. One hypothesis is that they have a positive association with primary reinforcement. A large body of research has supported the conditioned-reinforcement interpretation in which discriminative cues act as secondary reinforcers because of their association with primary reinforcement (Bowe & Dinsmoor, 1983; Case & Fantino, 1981; Case et al., 1985; Dardano, 1965; DePaulo et al., 1977; Dinsmoor, Browne, & Lawrence 1972; Fantino & Case, 1983; Gaynor & Shull, 2002; Heinemann et al., 1968; Shahan, 2002; Tomanari, 2004).

Others have stressed the role of informative properties of the discriminative stimuli as the maintaining variable for observing, given that they would reduce the uncertainty of the situation (Lieberman, 1972; Perone & Baron, 1980; Perone & Kaminski, 1992). The reduction in uncertainty would be reinforcing because it allows the organism to allocate its behavior in a way that optimizes access to primary reinforcement (Davis, 1983).
The information-based hypothesis suggests that observing is maintained by stimuli that signal the organism which behaviors lead to consequences correlated with particular circumstances. In this context, SDs associated with aversive as well as appetitive events might maintain observing while both stimuli provide the organism with information about the likelihood of important events. This hypothesis is consistent with assumptions about the function of observing (or attention). However, the behavioral research literature has not provided ample support for the information-based hypothesis. Lieberman (1972) conducted one of the few studies that provide evidence of the importance of both positive and negative stimuli in maintaining observing. In Experiment 1 the author investigated whether observing rates would increase with the enhanced value of the informative stimuli produced. The informative value of the stimuli varied depending on the probability of reinforcement with which it was correlated. In situations in which reinforcement was very frequent, the information provided by the stimulus was redundant because the reinforcement itself also provided this information. Rhesus monkeys were exposed to a typical observing situation in which two schedules of reinforcement for the food lever were concurrently presented and observing responses transformed the mixed schedule (no SD associated with either schedule) into a multiple schedule. In one component, different variable ratio (VR) schedules were used (from 5 to 100) across the experiment, while in the other, extinction was always in place. First, the results showed that reductions in the VR requirement (increases in the reinforcement rates) resulted in a substantial decrease in observing. Second, data indicated that some of the subjects emitted more observing responses in the condition in which the lever was
associated with the primary reinforcer during extinction. Lieberman concluded that these data lend support for the information-based hypothesis because the decrease in responding on the VR schedule represented a decrease in the informative value of the stimulus and because the informative value during extinction was greater due to the lack of reinforcement as an “additional clue”.

In Experiment 2, Lieberman (1972) further investigated whether changes just in uncertainty would affect observing. In order to do so, the rate of reinforcement was kept constant throughout the experiment. For half of the trials brief light flashes were added as a consequence for each response on the food lever. The idea was that the “extra” lights would produce redundant information and decrease the reinforcing value of the stimuli produced by observing. Observing increased significantly when the “extra” information produced by food lever responses was removed. Lieberman suggested that the informative value of the stimuli associated with observing was the controlling variable of observing.

Finally, Experiment 3 investigated whether the S- would reinforce observing despite its aversive conditional properties. For half of the sessions, observing produced S+ and S-, and for the other half, observing produced S+ but never S-. The results showed that “Withholding of S- in this experiment resulted in an immediate, sharp drop in observing rates, as would be expected if S- had been a secondary reinforcer” (Lieberman, 1972, p. 355). Lieberman concluded that although S- was not positively correlated with the primary reinforcer; its informative value established it as a secondary reinforcer. In view of the fact that the magnitude of the primary reinforcer (Shahan, 2002)
and deprivation states (Wehling & Prokasy, 1962) can also affect observing, Lieberman argued that the amount of information is not the only important variable in maintaining observing.

Perone and Baron (1980) further speculated on the role of information as a conditioned reinforcer. According to proponents of the information-based hypothesis, a positive stimulus-reinforcer correlation is not needed to establish a conditioned reinforcer; rather, the correlation may be positive or negative because information depends on the reliability, not the sign, of the stimulus-reinforcer relationship. Although research has suggested that this account may be supported (Lieberman, 1972), additional investigations are needed. This is especially true because there were methodological concerns with Lieberman’s study which is one of the only ones supporting the information-based account. Dinsmoor et al. (1977), for example, argued that baseline arrangements in Lieberman’s study (Experiment 3) did not serve as a fair comparison for responding during the experimental session.

Perone and Baron (1980), in Experiments 1 and 2, compared observing that produced stimuli correlated with periods of extinction (Exp. 1) or increased effort (Exp.2) with observing responses that produced only S+ or both S+ and S-. The results of Experiment 1 showed that S- maintained observing in humans when it was the sole consequence and it increased observing on the S+ key when S- was combined with the S+ as a possible consequence for observing. These data support the information-based hypothesis because S- proved to be a reinforcer for observing.
In Experiment 2, both components of the mixed schedule involved effort. This design was used in order to avoid interpretations that pointed to timeout from responding in the primary reinforcer lever (reduced effort) as the source of reinforcement for observing in Experiment 1. For the same reason, S- presentations were correlated with low-effort responses and S+ presentations were correlated with high-effort responses on the primary reinforcer lever. The results showed that observing was again maintained by both S+ and S-. By analyzing the pattern of responding on the primary reinforcer lever under mixed and multiple schedule conditions, Perone and Baron (1980) concluded that effort was not necessarily under discriminative control and that effort reduction was not the maintaining variable for observing.

In sum, Perone and Baron’s (1980) study supported the premise that information could function as a conditioned reinforcer and maintain observing. This is an uncommon outcome in the observing literature (see description of other studies below), which the authors suggested might be attributable to procedural differences. In addition, they proposed that the extent to which information functioned as a conditioned reinforcer might differ depending on the species of the subjects.

Some researchers have argued that, despite the intuitive appeal of information-based accounts, there are multiple sets of data that support the conditioned reinforcement interpretation for observing (Case & Fantino, 1981; Case et al., 1985; Dardano, 1965; DePaulo et al., 1977; Dinsmoor et al., 1972; Fantino & Case, 1983; Gaynor & Shull, 2002; Heinemann et al., 1968; Shahan, 2002; Tomanari, 2004). In addition, Dinsmoor’s (1985) discussion of the development of stimulus control suggests that the conditioned
reinforcement hypothesis may be more appropriate. The first account presented for this hypothesis was formulated by Skinner (1933, 1934, 1938, as cited in Dinsmoor, 1985) and Spence (1936, 1937, as cited in Dinsmoor, 1985). According to this account, the gradual development of stimulus control should be attributed to the growing strength of the behavior produced by continued reinforcement in the presence of one stimulus or the waning strength produced by extinction in the presence of the other stimulus. In other words, the final discrimination performance results from the accumulation of small differences. However, Dinsmoor pointed out that this account does not explain why the initial generalization of the strength of the $S^+$ to the $S^-$ and vice versa changes with the passage of the time. That is, if it is assumed that reinforcement increases the tendency of responding when the stimuli are present and extinction decreases such tendency, it is expected that the effects of both $S^+$ and $S^-$ would cancel each other out.

The second account presented in Dinsmoor’s (1985) review takes into consideration the observing response, which can increase the subject’s contact with the relevant stimuli and decrease its contact with irrelevant stimuli. According to this account, the initial “crossover” between the effects of reinforcement and extinction in the presence of the positive and negative stimuli might occur due to the failure to observe the stimulus that signals one or the other. However, during discrimination training, appropriate observing behavior should be acquired. According to Dinsmoor, the literature in orthogonal discrimination training supports the observing response account and not the gradual strength account. In orthogonal discrimination studies, the participant is trained to discriminate between the presence and absence of a given stimulus and then is tested.
with variations on some aspect of that same stimulus (e.g., DePaulo et al., 1977). The results have shown that discrimination training produces sensitivity to some aspects of the trained stimulus, whereas the absence of this training has no effect on the sensitivity to aspects of the untrained stimuli. Researchers have concluded from these studies that observing was maintained by the production of safety signals (S+), i.e., discriminative stimuli associated with reinforcement.

Another body of literature reviewed by Dinsmoor (1985) that supports his interpretation comes from studies that involve progressive training (e.g., Terrace, 1963a, 1963b). Findings in this area indicate that negative stimuli exert less control over responding following successive discrimination training than do positive stimuli. The relatively poor control exhibited by the S- could be explained by the reduced time spent observing S-. Dinsmoor argues that the extended exposure in the presence of the S+ is responsible for the greater degree of control exerted by the positive stimulus when the gradients of generalization are compared for S+ and S-. This explanation is supported by studies that show that when the stimulus element or feature that distinguishes the positive trials from the negative trials is programmed on the positive trials, pigeons learn a discrete-trial or autoshaping discrimination quite readily as compared to when that feature appears on the negative trials.

Gaynor and Shull (2002) also support this interpretation. They suggested that observing is maintained by the production of S+ or, as it is more frequently discussed, by conditioned-reinforcement. According to them, the conditioned-reinforcement hypothesis is supported when access is restricted to only one of the two stimuli (S+ or S-) and the
effects are dramatically different. More specifically, observing is maintained at high rates only when it produces S+, but declines to a lower level when it produces only S-. This is inconsistent with the information interpretation which predicts that both discriminative stimuli would produce useful information. On the other hand, it is consistent with the conditioned reinforcement view in which S+ becomes a conditioned positive reinforcer for observing and S- becomes a conditioned aversive stimulus (Dinsmoor, 1983; Fantino 2001).

In addition, Gaynor and Shull argued that studies on selective responding (e.g., Browne & Dinsmoor, 1974) provide further evidence supporting the conditioned-reinforcement hypothesis. Selective responding of observing occurs when subjects generate greater exposure to stimuli correlated with reinforcement than to extinction. This might occur by avoiding contact with the discriminative stimuli (e.g., looking away), by refraining from emitting the behavior that keeps the discriminative stimuli on (e.g., pressing a pedal) or by constantly emitting the behavior associated with the presentation of the positive stimulus. Selective observing is critical in interpreting results dealing with observing responses because even when S+ and S- are produced at similar rates, the total sum of conditioned positive reinforcement exposure can be made greater than the total sum of exposure to the conditioned aversive stimulation by selective observing. For example, the subject might emit the observing response and look away as soon as the aversive discriminative stimulus is presented, but continue to attend to the stimulus when it is an S+. In studies in which the rate of observing is similar in the presence of both S+ and S-, differences in exposure due to selective observing would support the conditioned
reinforcement hypothesis and not the information-based hypothesis as the data would suggest initially.

Gaynor and Shull (2002) investigated the conditioned reinforcement hypothesis and took selective observing into consideration when analyzing their results. Selective observing was investigated in a very innovative way -- it was evidenced by the latency of follow-up responses given after S+ and S-. In their arrangement, the subject could not control the duration of the S^D produced by observing. The results showed selective observing in favor of the S+ in three of the four rats and some evidence for the 4th. In other words, results suggested that S+ set the occasion for maintenance of observing (short follow-up responses) and S- set the occasion for its termination (long follow-up responses) when subjects were not able to control the duration of the discriminative observing presentation.

In addition, the study provides evidence for the generality of selective responding for rats as opposed to pigeons and mixed schedules in which both components offer intermittent food reinforcement. The latter is relevant because it shows that even when S- signaled food, the density of the primary reinforcement controlled responding. This would be expected in a conditioned reinforcement account. Finally, the authors indicated that the use of VI schedules on the food lever was essential for the outcome as it allowed follow-up observing responses without compromising optimal rates of responding on the food-lever correlated with the primary reinforcer. Gaynor and Shull (2002) concluded that the information hypothesis could not account for differential latencies to reinitiate contact with S+ and S- because both are similarly reinforcing from the informative point
of view. They also suggested that although the maintenance of S- is aversive (explaining why selective observing occurred), the onset of S- might be reinforcing due to its possible informative function. However, post-hoc analysis data showed that performance was less efficient when discriminative stimuli were contingent on observing than when no discriminative stimuli were present. In sum, even when faced with alternative information based explanations, the pattern of observing obtained in the study supports conditioned reinforcement interpretations on the maintenance of observing.

Shahan (2002) replicated and extended Gaynor and Shull’s (2002) findings. Based on the premise that observing is maintained by conditioned reinforcement, the author studied how basic parameters (e.g., rate, magnitude) of the primary reinforcer affect the rate of observing responses in rats. Observing was defined as any response on a lever that never produced food, but produced different discriminative stimuli (lights). One of the lights was correlated with reinforcement and the other with extinction. In Experiment 1, the response requirements to obtain the primary reinforcer were manipulated and the effects on the rate of observing were measured. The results indicated that increases in the response requirement produced an increase in the rate of observing behavior until a critical point (RR 100) when decreases in observing rates occurred. In other words, demanding very high rates of responding competed with observing while responding to the observing key decreased the opportunities for reinforcement on the primary reinforcement key. When the response requirement for the primary reinforcer was removed in Experiment 3, observing responses increased. In sum, these results, in combination with those from Experiment 1, confirm those found by Gaynor and Shull
(2002) and emphasize that response requirements on the primary reinforcer lever can interfere with observing rates (see also Tomanari, 2004).

Shahan (2002) (Experiments 2 and 4) also investigated how the dimensions of the primary reinforcer can interfere with observing, providing further evidence for the conditioned reinforcement hypothesis. Experiment 2 examined the effects of manipulating the magnitude of the primary reinforcer on observing while the response requirement for the primary reinforcement was held constant. Results showed that observing decreased as a function of the decreasing magnitude of the primary reinforcer. Experiment 4 studied the effects of different rates of the primary reinforcer on observing without changing the response requirements. Observing decreased as the rate of the primary reinforcer decreased. These results indicated that observing was affected not only by magnitude and rate of the primary reinforcer, but also by the behavior that led to the primary reinforcer. This suggests that observing is a complex behavior that is influenced by multiple variables. These variables must be taken into consideration in order to advance knowledge about the phenomena.

Shahan et al. (2003) also studied the effects of rates of primary reinforcers on observing; however, they used resistance to change to assess the impact on observing. Resistance to change is an alternative measure for responding in which decreases in the response rates relative to baseline are recorded after the introduction of a disrupter (e.g., presession feeding). Two experiments were conducted in which pigeons were exposed to a mixed schedule of reinforcement. In the rich component, observing responses produced stimuli (changing the schedule to a multiple schedule) correlated with high rates of
random-interval (RI) reinforcement or extinction. In the lean component, the stimuli produced were correlated with lower rates of RI reinforcement or extinction. Experiments 1 and 2 were very similar with the exception of the following manipulations. Experiment 1 used FI .75 s and Experiment 2 used a RI 15 s schedule of reinforcement for responses to the observing key (which produced the S\textsuperscript{D}s). In addition, Experiment 2 used both intercomponent interval (ICI) response-independent food delivery and presession feeding as disruptors, whereas in Experiment 1 only the latter was used.

In both experiments, observing was more resistant to change and occurred at a higher rate in the rich reinforcement component. In addition, observing rates were generally higher during non-signaled extinction conditions than during non-signaled RI conditions. However, when resistance to change was used as a measure, rates were higher during the non-signaled RI conditions than during non-signaled extinction. The differential resistance to change in observing when it was likely to produce S\textsuperscript{+} suggested that it was affected by the percentage of time spent in S\textsuperscript{+}. In other words, the results stress the value of resistance to change procedures as a measure of the reinforcing value of S\textsuperscript{+}. Overall, the authors concluded that observing may be quantitatively sensitive to relative reinforcement rates, replicating the findings with typical operant responses (e.g., lever presses) that use resistance to change as a measure.

Case and Fantino (1981) conducted two experiments with pigeons to explore the conditioned-reinforcement hypothesis. However, positive and negative discriminative stimuli were established in a slightly different manner than usual. The positive and negative value of the stimuli produced by the observing response was determined by their
correlation with shorter or longer fixed interval schedules of reinforcement. Usually, stimuli value is acquired by association with denser or thinner schedules (e.g., FR 2 and 8). According to Case and Fantino, although both methods are based on a similar rationale and share common predictions, research on choice favors the use of delay-reduction (e.g., Squires & Fantino, 1971). However, because the conditioned-reinforcement approach is most commonly used in the observing literature, in this paper both interpretations will be used interchangeably.

In Experiment 1, Case and Fantino (1981) assessed the delay-reduction hypothesis when the mixed schedule consisted of three components. They hypothesized that the results from three-component mixed schedules would be more stringent than those obtained from two-component mixed schedules. Differential observing could occur when $S^+$ was compared to a stimulus correlated with a smaller delay, and to each of the other two pairs of the three possible pairwise comparisons. In addition, Case and Fantino argued that the use of a three-component procedure would be helpful in testing the uncertainty-reduction hypothesis given that the increase in the complexity of the situation would increase the reinforcing value of the informative stimulus. The rate of observing maintained by the stimulus increased as a function of the degree of delay reduction associated with that stimulus, thereby supporting the delay-reduction hypothesis. For the same reason, the findings were inconsistent with the uncertainty-reduction hypothesis that predicts that all stimuli would have the same reinforcing value. However, because responding still occurred when the stimulus was associated with extended delay, it is necessary to explain the source of reinforcement for this behavior.
In Experiment 2, Case and Fantino (1981) investigated whether the sensory change produced by the stimulus following observing was responsible for the observing found when the stimulus produced was correlated with the increase in delay. The results showed that stimuli correlated with an increase in delay maintained less observing than stimuli that were uncorrelated (S\textsuperscript{U}) with reinforcement. These results suggested that sensory change maintained observing responses when it produced S-. However, due to its aversive properties, it produced less observing than the S\textsuperscript{U}. The results of Experiment 2 strengthened the conclusions found in Experiment 1. Specifically, the delay-reduction or conditioned-reinforcement interpretations are most suitable for explaining observing.

The previous studies suggested that observing responses are maintained by conditioned reinforcement, that is, by S\textsuperscript{+} presentations; however, the effects of the rate of the conditioned reinforcer in the observing response were not investigated. Shahan and Podlesnik (2005) studied these effects by using resistance to change as a measure of the effects of the conditioned reinforcer in observing responses emitted by pigeons. The studies with primary reinforcement indicated that responses maintained by high rates of reinforcement are more resistant to change than those maintained by lower rates of reinforcement (for reviews, see Nevin, 1992; Nevin & Grace, 2000). To the extent that conditioned and primary reinforcers are functionally equivalent, similar results should be obtained.

In Experiment 1, Shahan and Podlesnik (2005) investigated the effects of different rates of stimulus presentation (conditioned reinforcer) on observing when the rate of the primary reinforcer was constant. The results showed that observing rates were higher in
the rich component; however, resistance to change was not differentially affected by the rate of the conditioned reinforcement. In fact, responses in the lean component tended to increase when the disruptor used was extinction. In Experiment 2, the rate of stimulus production was increased (from 4:1 to 6:1). The results were similar to Experiment 1 making even clearer the tendency of observing to be more resistant to change in the lean component. These results suggested that higher rates of conditioned reinforcement maintained higher response rates but did not affect resistance to change. The authors questioned what measure of responding would be more appropriate to determine the effects of conditioned reinforcement on response strength.

Fantino and Case (1983) discussed differences among subjects on the phylogenetic scale as a possible explanation for the contradictory results regarding the variables that maintain observing. They point out that most of the studies supporting the informative hypothesis (e.g., Lieberman, 1972; Perone & Baron, 1980; Schrier, Thompson & Spector, 1980) had primates as subjects, whereas many of the studies that support the conditioned-reinforcement hypothesis were conducted with pigeons or rats (i.e., animals on an inferior level in the phylogenetic scale). In order to assess evolutionary status as a critical variable, Fantino and Case conducted their study with human participants. In addition, they also investigated the influence of instructions on students’ responding and verbal reports, given that this is one of the main characteristics that differentiate humans and non-humans. Finally, Fantino and Case assessed observing using response-independent reinforcement in an effort to replicate Perone and Baron (1980) without effort as a confounding variable.
Fantino and Case’s (1983) four experiments support the conditioned-reinforcement hypothesis. Participants emitted more observing when it produced a new stimulus (S") than when it produced the S-. Moreover, under a variety of instructional formats, responding was consistent. This suggests that regardless of the influence of instruction on human observing, the contingencies had greater control over responding than did instructions. Finally, although support for the information hypothesis was not obtained, the authors speculated that the results reported by Perone and Baron (1980) were affected by the impact of observing on the distribution of effortful responses.

Case et al. (1985) also attempted to clarify the circumstances under which S- might reinforce human observing behavior. They investigated the effects of conditions that varied according to whether observing would or would not be correlated with a more efficient distribution of the response required for reinforcement. In other words, they examined Fantino and Case’s (1983) contention that response efficiency had a central role in Perone and Baron’s findings. In Experiment 1, both components of the mixed schedule were identical (VI 30s); however, each of them was associated with different amounts of reinforcement. Therefore, the amount of lever pressing should be lower in the

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1 In Perone and Baron’s study, observing was emitted in similar rates under S- and S+ productions. Although it seemed an indication that information was maintaining observing, the authors argued that observing might have been present under S- conditions because it was a less effortful response (5lb) that allowed the participants to emit fewer responses on the most effortful plunger (15 or 20lb). Hypothetically, if plunger responding was aversive due to the effort associated with it then its suppression in the EXT component should be reinforcing. Therefore, the stimulus correlated with suppression (S-) should become a conditioned reinforcer by association. Fantino and Case (1983) suggested a replication of the study with response-independent schedules controlling for effort to clarify this question.
presence of the less positive $S^D$ (associated with the smaller amount of reward), while the amount of effort saved by observing would be relatively small. Results confirmed that the amount of reinforcement associated with each component of the schedule yielded different rates of responding. Specifically, responding was more frequent in the component associated with the larger amount of reinforcement. This is consistent with the conditioned-reinforcement hypothesis. In addition, the stimulus that was uncorrelated with reinforcement ($S^U$) was preferred over the $S-$; further supporting this hypothesis.

Experiment 1 confirmed that responding was not maintained by the $S-$ even when response requirement schedules were used in both components. Experiment 2 investigated the effect of varying the response efficiency enabled by observing. Results showed that when the production of $S-$ enabled a substantial improvement in response efficiency (because participants could reduce ineffective responding on a relatively high effort manipulandum), college students observed the $S-$ more than the $S^U$. Conversely, when observing no longer affected efficiency of responding, the same participants preferred the $S^U$ over the $S-$. Case et al. (1985) argued that when extinction is correlated with savings of effort, the predictions of the conditioned-reinforcement hypothesis cannot be specified; however, the preference for $S-$ only under certain conditions lends supports to the hypothesis that uncertainty reduction is not a determinant of observing for more highly evolved organisms.

Perone and Kaminski (1992) argued that studies further investigating Perone and Baron (1980) (e.g., Case & Fantino, 1981; Fantino & Case, 1983) used substantially different experimental strategies to investigate human observing than those used in the
nonhuman animal research. In studies with nonhumans, stimulus-reinforcer relations are engendered due to exposure to a history of reinforcement. That is, stimulus control is established by its correlation with reinforcement and extinction. Some studies with humans, on the other hand, use response-independent schedules and stimulus control is established by instruction. In addition, in order to control for the issues related to effort (see Fantino & Case, 1983; Perone & Baron, 1980), but still allow assessment of stimulus control in the traditional way (i.e., due to exposure), Perone and Baron used low-effort keys for both observing and primary reinforcement. This would make any “effort” involved in the experiment minimal and, consequently, unlikely to control behavior.

Using a response-dependent procedure and instructions similar to those used by Fantino and Case (1983), Perone and Kaminski (1992) investigated the maintenance of observing both before and after extended contact with the stimulus-reinforcer relations (see Experiments 1 and 2). Fantino and Case’s instructions imply a causal relation between observing the $S^U$ and receiving points; however, this relation might not have been perceived due to the short exposure to the contingencies. This could explain why the $S^U$ was preferred over the $S^-$. Nevertheless, in Perone and Kaminski (1992), college students reliably preferred $S^U$ to $S^-$ during short and extended exposure to the contingencies.

In order to further investigate the role of procedural differences in the referenced studies, Experiment 3 was designed to reduce the possibility of instructional control over responding. Similar to studies with pigeons and rats, the discriminative stimuli that were used had only an arbitrary relation with the primary reinforcement. The results showed
that S- was preferred over S^U, providing support for the information-based hypothesis (i.e., stimulus correlated with extinction can reinforce human observing). The authors concluded that changes in responding occurred due to the weakened instructional control contrived in Experiment 3. Perone and Kaminski (1992) speculated that lack of instructional control might have increased the participants’ susceptibility to reinforcement by information. Nonetheless, the authors argued that “A satisfactory theoretical explanation for the phenomenon of reinforcement by information remains to be developed” (p. 574).

In sum, basic researchers have been studying observing for almost 40 years, yet a conclusive statement regarding the maintaining variables has yet to be established. Fortunately, the confluence of the research to date has provided information that can be used as a basis for further investigation of the phenomena. First, advocates of the information-based hypothesis have suggested that although information seems to be the logical maintaining variable for observing, only primates have shown the potential to be reinforced by it. Most studies with other species, including with humans, have shown behavior patterns that are more consistent with the conditioned-reinforcement hypothesis. Second, even when information was shown to be a reinforcer for observing, researchers would still agree that other variables could maintain observing (Shahan, 2002).

These findings suggest that when investigating attention deficits in children with ADHD, it is important to take in consideration that the information that is captured is not necessarily the reason why these children will increase or decrease their attention levels. Some other variables that could be influencing their behavior can be found in the studies
with animals that support the conditioned-reinforcement hypothesis. These studies indicate that (a) positive stimuli exert more control over subsequent responding than negative stimuli; (b) even when observing rates are similar under the presence of both S+ and S-, selective responding of observing generates greater exposure to the S+ than to the S-; (c) response requirements for the primary reinforcer affect observing rates (especially when they compete with observing and/or when they impose much more effort than the observing response); (d) the dimensions of the primary reinforcers exert control over observing; (e) the sensory changes that occur after observing can maintain some level of observing; and (f) higher rates of conditioned reinforcement maintain higher observing rates but do not affect its resistance to change.

Finally, studies with human participants have repeatedly manipulated variables such as instructional control, effort, and response requirements in order to develop an explanation regarding the role of instruction, stimuli informative value, and conditioned-reinforcers on observing. Fantino and Case’s (1983) data suggested that regardless of the format of the instruction, participants emitted more observing in the presence of S+ or SU than in the presence of S- when the primary reinforcement was independent of responding (thus, no effort was involved). Case et al. (1985) investigated the impact of effort on observing using response-dependent schedules and instructions that were similar to the previous studies. When observing was correlated with a more efficient distribution of responses required for reinforcement, S- maintained more observing than the SU. The authors suggested that effort influenced observing and could explain why different studies with or without effort interference yielded different results. Finally, Perone and
Kaminski (1992) suggested that if instructions were not provided, the information provided by the S-stimulus could maintain observing even when effort is not an influential variable. Although the mechanisms that maintain observing in humans have yet to be fully explained, these studies have identified important variables that must be considered when studying and/or changing observing or attending patterns of children with ADHD.

*Matching to sample procedures*

Individuals with mental retardation and autism commonly demonstrate a pattern of behavior that is known as “stimulus selectivity” or “restricted stimulus control”. This pattern of behavior is characterized by responding that is controlled by only one element of the discriminative stimuli while the others are ignored (Stromer, McIlvane, Dube, & Mackay, 1993). This is a deficit that falls under the phenomena of attending and studies in this area might help us better understand its controlling variables and different ways of investigating it.

Dube and McIlvane (1997) used a delayed matching to sample with multiple sample stimuli to investigate the effects of reinforcement rates on responding that was under restricted stimulus control. Baseline trials provided different reinforcement rates for two sets of stimuli during identity matching tasks with one sample. During test trials, the task involved two sample stimuli, one of which was correlated with a high rate of reinforcement and the other with a lower rate. The results showed that stimuli correlated with higher rates of reinforcement controlled accurate responding more frequently. In
other words, reinforcement history influenced the sample stimuli that would exert stimulus control. These results are consistent with those from the experiments described earlier using observing responses. They suggest that stimulus control is more likely and observing is more persistent when the target stimulus is associated with reinforcement. Once more, it seems that remediation of attention problems might depend on the reinforcement history with the stimulus. These findings seem to be in accordance with data that show that stronger and more salient reinforcers decrease attention problems in children with ADHD (Barkley, 2006; Craig & Holland, 1970). That is, it seems that increasing the reinforcing value of the conditioned reinforcer produces higher levels of attention.

Geren, Stromer, and Mackay (1997) also used matching to sample to investigate the use of a remedial procedure called differential observing response (DOR) to increase stimulus control. DOR is a procedural modification that may improve discrimination by requiring differential responding in the presence of the sample stimuli. DOR procedures control observing and verify discrimination of critical stimulus features. Geren et al. examined the effects of a DOR (naming the sample picture aloud) on the percentage of errors during delayed picture-picture matching trials. The results showed that requiring a naming response and giving differential feedback for the naming decreased errors. On the other hand, increases in delay during matching trials increased errors. The authors concluded that improvements in performances might have occurred because naming ensured observation of the samples.
Dube and McIlvane (1999) also investigated the use of a DOR to increase performance on a matching to sample task with two sample stimuli. However, because naming is not always an available DOR, a simultaneous identity matching task was used as the DOR. That is, an additional identical matching to sample response without delay was required, prior to the presentation of the delay matching task that was being thought. Simultaneous identity matching trials consisted of the simultaneous presentation of the compound model on the center of the screen and three compound comparisons. Touching the identical comparison stimulus initiated the delayed trial. During the delayed trials, a compound stimulus was presented followed by the presentation of three single comparisons. Correct responses were selection of the stimulus that was a component of the sample. Because previous studies have shown that a history of reinforcement can interfere with observing, DORs in this study were not followed by reinforcement. Results showed that the use of the DOR increased accuracy during delayed matching. The authors suggested that the DOR procedure increased observing of the sample, setting the occasion for discrimination of both stimuli of the sample. Unfortunately, no lasting effects were observed after the DOR was withdrawn.

Walpole et al. (2007) extended Dube and McIlvane (1999) on the use of a DOR as a strategy to increase accuracy in matching to sample tasks. Children with autism were exposed to two different types of matching to sample tasks. In non-overlapping trials, sample and comparisons differed for all three of the letters that formed each word (e.g., cat, lid, and bug). In overlapping trials, sample and comparisons differed according to only one of the three letters of the words (e.g., cat, can, and car). Responding during
overlapping trials showed that behavior was under restricted stimulus control of only the first letter of each word of the model and the comparisons. In order to address this problem, a DOR was used before the presentation of the overlapping trials. The DOR response was also a matching to sample task in which only the letters that differed among the overlapping words were compared (e.g., t, n, r). The introduction of the DOR was effective in increasing accurate responding during the overlapping trials even after the DOR requirement was removed. The authors concluded that the use of the DOR procedure was effective in broadening the range of observing behavior during stimuli presentation.

Future research

It is important to better understand the role of attention in ADHD in order to develop effective interventions that enhance academic functioning. There are numerous perspectives on the nature of attention and the variables that influence it. Depending on the field in which it is being studied and/or the definition that is used, attention appears to be maintained by different variables (e.g., delay avoidance, information and conditioned reinforcement). In fact, even when similar procedures and definitions are used, findings have been inconclusive. Therefore, our knowledge about the best way to measure, control and predict attention is also limited.

Barkley (1991) and Solanto et al. (2001) point out that a direct measure of the phenomena of interest (attention) is not available in applied settings. Therefore, a plethora of alternative measures with questionable validity or reliability have been
adopted. In addition, Purdie et al. (2002) suggested that one possible explanation for the weak impact of ADHD interventions on students’ academic achievement may be inherent in the use of pre- and post-test designs. DuPaul and Stoner (1994) have argued that in order to determine the efficacy and/or limitations of the intervention program, assessment data should be collected on an ongoing basis throughout the treatment.

In addition, there is an urgent need to link assessment data and treatment. Usually, assessment is designed for the purpose of diagnosis rather than for evaluation of treatments of characteristics that interfere with learning. DuPaul and Ervin (1996) argue that ADHD diagnosis does not provide clinicians (or teachers) with sufficient information to determine specific interventions to use with each child. In one of the few studies that used data to predict treatment response, DuPaul and Ervin (1996) proposed that the context of the child’s ADHD symptoms should be taken into account. They used functional assessment methodology to investigate ADHD symptoms (e.g., attention). Based on the results, individualized treatments were proposed. Although results were encouraging, the use of a topographical measure of attending was a limitation of the study. Unfortunately, the consequences of the (in)attentional process (e.g., effects on performance) were not assessed.

Finally, although various treatments for attention deficits have been used and evaluated, knowledge of how to control observing/attending in an efficient manner is also still very limited. One possible reason for this lack of knowledge is the methodology that has been used to assess interventions. It is logical to conclude that without good
measurement, there is no way to know which variables control attending behaviors and how attending can be changed effectively.

Using the observing response and/or the matching to sample with DOR procedures can be a first step in developing an effective methodology for the study of attention in children with ADHD. These procedures would allow researchers to (a) isolate variables that affect attention, and (b) to investigate how increased attention impacts effective responding (performance). For example, the observing procedure was used by Case et al. (1985) to investigate differences in observing/attending when the stimulus that is attended either can or can not be correlated with a more efficient response distribution (for different examples see, Gaynor & Shull, 2002; Geren et al., 1997; Madden & Perone, 1999; Walpole et al., 2007).

Another advantage of using the observing response and matching to sample procedures to assess observing/attending is the fact that these procedures are suitable for use in schools. For example, these procedures could be (a) easily adapted to academic related tasks, (b) conducted with the use of a computer, and (c) used to inform intervention (see Walpole et al., 2007, as an example). In addition, measures based on the observing and matching to sample procedures could be validated as a screening tool in schools, which then could or could not be followed by traditional clinical measures. In fact, if laboratory measures go through a process to establish their ecological validity (e.g., Hoerger & Mace, 2006), such additional measures might not be even needed (at least in the educational context).
A third advantage of using the observing response and matching to sample procedures is the possible integration of previous knowledge with future findings. For example, future research could extend studies that investigate attention in other populations. Previous interventions with children with autism could help determine the extent to which DOR procedures would be an effective intervention to increase attending and performance in children with ADHD.

Finally, the possibility of using adaptations of the observing response and matching to sample procedures in applied contexts would make possible the use of individualized data to design interventions without practical restrictions, such as teacher time, treatment integrity, and fairness to the other students.

In conclusion, the use of the observing responses and matching to sample procedures is a very promising first step. In fact, procedures from basic research have already been successfully used by some authors to investigate impulsivity in children with ADHD: (Hoerger & Mace, 2006; Neef, Bicard, & Endo, 2001; Neef et al., 2005).

Attending or Impulsivity?

Although extensively studied, ADHD is still a controversial disorder. Traditionally, attention deficits have been the main focus of studies. Recently, some researchers have questioned if attention deficits represent distraction or lack of effort/motivation to attend (e.g., Hoza, Pelham, Waschbusch, Kipp, & Owens, 2001). These researchers argue that ADHD is not a disturbance in attention, but rather is the expression of an altered motivational state that leads to an altered response to
reinforcement parameters (especially magnitude and delay). According to one expert, “Compelling evidence exists that ADHD comprises a deficit in the development of behavioral inhibition.” (Barkley, 2006, p. 318). Nigg (2001) defends the notion that disinhibition offers a potentially parsimonious, integrative and testable theory about the origins of ADHD. Nevertheless, the definition of inhibition is theoretically confusing and definite conclusions about its role in ADHD are tenuous.

Sonuga-Barke et al. (1994), for example, have argued that inattention, overactivity, and impulsivity, can be seen as expressions of delay aversion. Although formally distinct clinical manifestations, they can be viewed as functionally equivalent with the underlining function being the escape, avoidance, or at least reduction of delay. That is, inattention and overactivity in children with ADHD represent attempts to reduce the perceived (but not the actual) length of time passing.

Catania (2005) supports this conceptualization by stating that the various symptoms defining ADHD should be attributed to anomalies of delay-of-reinforcement gradients. For example, attention deficits would occur due to the impact that steepened gradients have on the effectiveness of the conditioned stimuli that maintain attention. In other words, the delay aversion displayed by children with ADHD would impact attention because of its impact on the potency of the conditioned reinforcer that is associated with the delayed reinforcer. Impulsivity, on the other hand, would occur because a steepened delay gradient would make a smaller immediate reinforcer always more valuable than a delayed reinforcer of any size.
In order to support his account, Catania (2005) argues that different levels of delay gradients could also account for the individual differences in the balance between hyperactivity and attention deficits. For example, “for an individual whose gradient drops asymptotically to near zero within a second or so,” hyperactivity should not be a problem, as there will be no opportunity for sequences of behavior to be reinforced. However, severe attention deficits should occur because only very brief stimuli can acquire conditional reinforcing effectiveness.

Regardless of the theory, recent conceptualizations assume that all symptoms presented by children with ADHD are related behavioral inhibition rather than to a deficit in attention per se (Barkley, 2006; Nigg, 2001). If this is true, managing impulsive responding would impact performance more strongly than assuring attention relevant stimuli. Future research must investigate such a possibility so interventions focus on the “real” source of the attentional/achievement issues presented by these children.
CHAPTER 3

METHOD

Participants and Setting

Eight children between the ages of 6 to 12 participated in the study. All participants attended a public urban elementary school in a low income neighborhood (68% of the students in the school qualified for free or reduced lunch). Four students with a diagnosis of ADHD were enrolled based on the following criteria: (a) They had a record of consistent school attendance, as verified by the participant’s teacher; (b) their classroom teacher recommended them as likely to benefit from participation; (c) they met the DSM-IV diagnostic criteria for ADHD; (d) their parents or guardian granted consent for participation (see Appendices A and B) (e) their parents agreed that medication status would not be changed during the duration of the study, and; (f) they demonstrated acquisition level performance (i.e., between 60 % to 100% correct and/or a low rate of responding) on three different types of mathematics problems. Four typically developing children who met the same inclusion criteria except for a diagnosis of ADHD were enrolled. They had demographic characteristics similar to the participants with a diagnosis of ADHD (e.g., age, grade).
The purpose and all procedures were described to building administrators from whom consent to conduct the study in the school setting was obtained (see Appendix C). Approval to conduct the study was obtained from the Institutional Review Board of The Ohio State University.

All 4 participants without ADHD were females. Two were in first grade and the other two were in third grade. Three of the participants with ADHD were male and one was a female. All of them were taking medication for treatment of ADHD symptoms. Medication doses were kept constant throughout the experiment (see Table 3.1 for a detailed description of each participant). Demographic information was collected on a confidential datasheet (see Appendix D).

Sessions were conducted three to five times per week in a separate room of the school. The room was equipped with three tables and various school materials.
<table>
<thead>
<tr>
<th>Student</th>
<th>Age</th>
<th>Gender</th>
<th>Race</th>
<th>Grade</th>
<th>Diagnosis</th>
<th>Medication Type/Dosage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anna</td>
<td>6</td>
<td>Female</td>
<td>Caucasian</td>
<td>First</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Denise</td>
<td>6</td>
<td>Female</td>
<td>Hispanic</td>
<td>First</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Dan</td>
<td>8</td>
<td>Male</td>
<td>African-American</td>
<td>Multiple Disabilities</td>
<td>ADHD</td>
<td>Dextedrine 50 mg/ 1 day</td>
</tr>
<tr>
<td>Alan</td>
<td>7</td>
<td>Male</td>
<td>Caucasian</td>
<td>Second</td>
<td>ADHD</td>
<td>Adderall XR 25 mg/ 1 day</td>
</tr>
<tr>
<td>Donna</td>
<td>9</td>
<td>Female</td>
<td>Caucasian</td>
<td>Third</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Heather</td>
<td>9</td>
<td>Female</td>
<td>African-American</td>
<td>Third</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Henry</td>
<td>9</td>
<td>Male</td>
<td>Caucasian</td>
<td>Third</td>
<td>ADHD ASD</td>
<td>Adderall 10 mg/ 1 day</td>
</tr>
<tr>
<td>Daisy</td>
<td>12</td>
<td>Female</td>
<td>Caucasian</td>
<td>Fifth</td>
<td>ADHD Manic Depression</td>
<td>Adderall XR 25 mg/ 1 day</td>
</tr>
</tbody>
</table>

Table 3.1. Participant characteristics
Apparatus and Materials

The experimental task was conducted on a Toshiba ® laptop using a software program that allowed the experimenter to choose specifications for each session (see detailed description under Procedures). The program involved the sequential presentation of mathematics problems within the parameters specified by the experimenter in each condition. The type of mathematics problem presented was the same within each condition, but the specific problems differed across conditions (i.e., the program randomly assigned different problems to be used in each condition). The computer program was equipped to record in each condition (a) the number of problems completed accurately and inaccurately, (b) the number of problems attempted, (c) the latency for responses, (d) session duration, (e) the number of choices for each condition within the choice sessions.

Other materials included writing utensils (e.g., pencil and paper), “price” labels for different rewards, rewards (e.g., juice box, candy, pens, balls), and datasheets with session logs.

Procedures

Experimental Task and Conditions

The experimental task involved the successive presentation of mathematics problem stimuli, to which participants entered a response. Each trial began with the presentation of the mathematics problem in the center of the screen (see Figure 3.1. for an example) or after the requirements of the Observing conditions ended. No indication of
time passage was provided. The problem remained on the screen until the participant entered an answer from the keyboard, and clicked the “OK” button. Correct answers were followed by a distinctive sound and the addition of a point on a screen showing the cumulative number of points earned during the session. Incorrect answers did not produce sounds or points, but the screen with cumulative points still appeared following each answer. Correct responses to mathematics problems were reinforced with points on a continuous schedule of reinforcement (CRF). Participants had a total of 10 minutes per session to complete as many problems as the time allowed (except during the pretest sessions).

A pool of at least 20 rewards nominated by the teacher and student as highly preferred were available for exchange (e.g., small toys, balloons, lollipops). Different items had different exchange values. Participants exchanged points for rewards at the end of the session.

The program provided a menu from which the experimenter selected the specifications for each session. The specifications consisted of: (a) The type of session that was being conducted (assessment or choice), (b) the condition to be presented (during the assessment sessions), (c) the color that would be associated with each condition, (d) the duration of wait time during Wait conditions, (e) the type (addition, subtraction, multiplication, or division) and level of mathematics problems, and (f) the session duration.

Each experimental condition was associated with a different color that had been randomly assigned. The beginning of each condition during assessment sessions was
signaled with a colored circle in the middle of the screen. A click on the circle initiated the first trial of the condition. In addition, the background color of the screen during each trial within the condition was the same as the colored circle associated with it. The beginning of each trial during choice sessions was signaled with a choice screen where all four colored circles were presented until the participants choose the condition that would be presented during the next trial. Choices were presented at the beginning of every trial.

![Computer screen at the beginning of each trial of the experimental task.](image)

*Figure 3.1.* Computer screen at the beginning of each trial of the experimental task.

*Mathematics Pretest.* The purpose of the pretest was to identify three types of mathematics problems that the participants performed at acquisition level. Acquisition level problems were those that could be performed at an accuracy level of 60% to 100%
correct and at a lower rate than same-grade peers. Problems that were performed below the established accuracy level were not suitable because errors would be likely caused by lack of knowledge in performing the mathematics operation and not because of attention deficits. High accuracy levels (close to 100 %) were accepted as long as the rate of correct responding performed by the participant was lower than the rates performed by a typical peer in the participant’s classroom. This criterion was included because participants with high accuracy rates might solve problems accurately while taking much more time to do so than is typical for same-grade peers.

Initial selection of problem type to be tested was based on teachers’ reports of students’ abilities. During each 5 min pretest session, participants answered different mathematics problems within the same category (e.g., single digit addition without regrouping). Up to 10 pretest sessions were conducted until three types of problems that were at acquisition level were identified. If three types of problems that met selection criteria could not be identified for a student, the student’s participation in the study was discontinued. This was the case for only one of the initial 9 participants for whom consent was obtained. Tables 3.2 and 3.3 show the types of problems that were selected for each participant, and the accuracy and rate levels obtained for those problems during the pretest.
<table>
<thead>
<tr>
<th>Name</th>
<th>Problem 1</th>
<th>% Correct</th>
<th>Problem 2</th>
<th>% Correct</th>
<th>Problem 3</th>
<th>% Correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anna</td>
<td>Addition: Sums 0-18</td>
<td>100</td>
<td>Addition: 3 number column w/out regrouping</td>
<td>87.5</td>
<td>Addition: 4 number column w/out regrouping</td>
<td>100</td>
</tr>
<tr>
<td>Denise</td>
<td>Addition: Sums 0-18</td>
<td>64.7</td>
<td>Addition: 3 number column w/out regrouping</td>
<td>85.7</td>
<td>Addition: 4 number column w/out regrouping</td>
<td>92</td>
</tr>
<tr>
<td>Heather</td>
<td>Addition: 2 number 3 column w/out regrouping</td>
<td>85</td>
<td>Subtraction: 2 digit w/out regrouping</td>
<td>100</td>
<td>Subtraction: 3 digit with 2 or 1 digit w/out regrouping</td>
<td>83</td>
</tr>
<tr>
<td>Donna</td>
<td>Addition: 3 number 2 column w/out regrouping</td>
<td>85</td>
<td>Addition: 2 number 3 column w/out regrouping</td>
<td>92</td>
<td>Subtraction: 2 digit w/out regrouping</td>
<td>73.3</td>
</tr>
<tr>
<td>Alan</td>
<td>Addition: Double digit and single digit without regrouping</td>
<td>90</td>
<td>Addition: 3 number 2 column w/out regrouping</td>
<td>100</td>
<td>Subtraction: 2 digit w/out regrouping</td>
<td>100</td>
</tr>
<tr>
<td>Dan</td>
<td>Addition: Sums 0-18</td>
<td>100</td>
<td>Addition: 3 number column w/out regrouping</td>
<td>63</td>
<td>Addition: 4 number column w/out regrouping</td>
<td>100</td>
</tr>
<tr>
<td>Henry</td>
<td>Addition: 2 number 3 column w/out regrouping</td>
<td>100</td>
<td>Subtraction: 2 digit w/out regrouping</td>
<td>86.6</td>
<td>Subtraction: 3 digit with 2 or 1 digit w/out regrouping</td>
<td>60</td>
</tr>
<tr>
<td>Daisy</td>
<td>Subtraction: 3 digit with 3 digit with regrouping</td>
<td>72.7</td>
<td>Multiplication: Single digit X double digit with regrouping</td>
<td>100</td>
<td>Multiplication: Double digit X double digit with regrouping</td>
<td>75</td>
</tr>
</tbody>
</table>

*Table 3.2.* Problem types selected for each participant during the pretest. Performance was measured by the percentage of correct responses for each problem type assessed.
<table>
<thead>
<tr>
<th>Grade</th>
<th>Participants</th>
<th><strong>Addition</strong></th>
<th><strong>Subtraction</strong></th>
<th><strong>Multiplication</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Sums 0-18</td>
<td>3 number column w/out regrouping</td>
<td>4 number column w/out regrouping</td>
</tr>
<tr>
<td>1st</td>
<td>Anna</td>
<td>2.3</td>
<td>2.99</td>
<td>1.58</td>
</tr>
<tr>
<td></td>
<td>Denise</td>
<td>2.64</td>
<td>2.71</td>
<td>2.71</td>
</tr>
<tr>
<td></td>
<td>Dan</td>
<td>1.44</td>
<td>1.06</td>
<td>1.51</td>
</tr>
<tr>
<td></td>
<td>Comparison</td>
<td>3.05</td>
<td>3.15</td>
<td>3.52</td>
</tr>
<tr>
<td>2nd</td>
<td>Alan</td>
<td></td>
<td>1.83</td>
<td>2.77</td>
</tr>
<tr>
<td></td>
<td>Comparison</td>
<td></td>
<td>3.91</td>
<td>6.21</td>
</tr>
<tr>
<td></td>
<td>Donna</td>
<td></td>
<td>2.51</td>
<td>2.37</td>
</tr>
<tr>
<td>3rd</td>
<td>Heather</td>
<td></td>
<td>2.43</td>
<td>3.85</td>
</tr>
<tr>
<td></td>
<td>Henry</td>
<td></td>
<td>2.48</td>
<td>2.97</td>
</tr>
<tr>
<td></td>
<td>Comparison</td>
<td></td>
<td>3.58</td>
<td>4.04</td>
</tr>
<tr>
<td>5th</td>
<td>Daisy</td>
<td></td>
<td></td>
<td>1.64</td>
</tr>
<tr>
<td></td>
<td>Comparison</td>
<td></td>
<td></td>
<td>2.29</td>
</tr>
</tbody>
</table>

*Table 3.3. Number of correct responses per minute for selected problems during mathematics pretest.*
Relevant observing response. Each mathematics problem presentation was preceded by a relevant observing response. The trial began with a matching-to-sample (MTS) task. A sample stimulus (target mathematics problem) was presented with four comparison stimuli below it. The comparison stimuli consisted of one mathematics problem identical to the sample stimulus and three mathematics problems which differed from the sample with respect to the type of mathematics operation represented (see Figure 2 for an example). A correct response was defined as a click on the comparison that was identical to the sample. When an incorrect response occurred, the sample and comparisons were re-presented until the correct comparison was chosen. Choosing the correct comparison produced a screen with only the sample problem to be solved (in the same manner as described for the pretest).

Figure 3.2. Computer screen during the Relevant Observing Condition
Irrelevant Observing Response. Procedures were the same as described in the relevant observing response condition except that the stimuli in the MTS task that preceded the problem were unrelated to the mathematics problem that was subsequently displayed. An example is presented in Figure 3.3.

Wait with No Observing Response. Trials began with the presentation of the mathematics problem to be answered; however, a fixed amount of time (equal to the mean amount of time for the observing response in the previous conditions) elapsed before an answer could be entered. This was signaled by the appearance of the rectangle (space for entering the answer) and the appearance of the “OK” button. Keystrokes (attempts to enter an answer) during the wait time did not produce changes on the computer screen.

No Wait. Procedures were identical to those described for the pretest, except that the sessions lasted for 10 minutes.

Choice. Four colored circles were displayed in the initial screen, each corresponding to one of the four conditions. By clicking on a specific color, participants were able to choose the condition that would be presented for that trial.
Dependent Measures

Four dependent measures were calculated based on (a) the number of problems completed accurately and inaccurately, (b) the number of problems attempted, (c) the latency for responses, (d) the session duration, and (e) the number of choices for each condition within the choice sessions. The first dependent measure was the percentage of correct responding to mathematics problems during conditions. Percentage of correct responding was calculated by dividing the number of correct responses by the total number of problems attempted during that session and multiplying the result by 100.
The second dependent measure was the number of correct responses per minute. Rate of correct responding was calculated by multiplying the number of correct responses during the condition by 60 and dividing the product by the total amount of time spent resolving the mathematics problems. During Observing conditions, time spent on the MTS task (before problems solution) was not counted so that session duration was constant across conditions.

The third dependent measure was the percentage of choice for each condition. Percentage of choice was calculated by dividing the number of times a particular condition was selected in the choice phase by the total number of choices made for all conditions and multiplying the result by 100. Choice allowed determination of the relative preference for each of the four conditions. Preference was identified when a specific condition was chosen for more than 50% of the time.

The fourth dependent measure was mean latency of responses during the identity MTS of the Relevant Observing condition that followed correct and incorrect responses on the mathematics problems. The first step to obtain the mean latencies during MTS that lead to correct responses on the math problems was to add the latencies from sample presentation to comparison selections that were followed by a correct response on the mathematics problem. Then, the total obtained was divided by the number of correct responses and multiplied by 100. Calculations of the mean latencies during MTS that led to incorrect responses on math problems were obtained in a similar manner, by using latency values associated with responses that led to incorrect answers.
Experimental Design and Data Analysis

An alternating treatments design was used to evaluate the effects of observing requirements and delay aversion on the percentage and rate of correct responses on mathematics problems. First, comparisons between conditions with the relevant and irrelevant observing response requirements enabled examination of the effects of ensuring control by relevant stimuli on subsequent performance of problems (percentage and rate of correct responding). Second, comparisons between conditions with and without a wait requirement helped determine the role of delay aversion on the percentage and rate of correct responding.

Each participant was repeatedly exposed to four conditions (relevant and irrelevant observing, wait and no wait). Each condition was associated with a unique discriminative stimulus (color) to enhance discrimination. The order of presentation of the first four conditions was alternated across experimental blocks and counterbalanced across participants (see Table 3.4). In order to control for carryover effects, each of the conditions was conducted with a different set of problems within the pre-selected types of problem. Choice sessions were conducted after each presentation of a block of all four conditions in order to determine which condition was preferred by the participant. The preference for a specific condition also helped inform different patterns of responding for children with and without ADHD.
<table>
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<th>3rd</th>
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<td>N R W I C</td>
<td>N R W I C</td>
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<td>R W I N C</td>
<td>I N R W C</td>
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<td>_____</td>
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<td>R W I N C</td>
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<tr>
<td>Dan</td>
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<td>R N I W C</td>
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<td>R W I N C</td>
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<tr>
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<td>N R W I C</td>
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<td>_____</td>
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<tr>
<td>Daisy</td>
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<td>N R W I C</td>
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</table>

*Table 3.4. Order of exposure to each condition across participants. R: Relevant Observing; I: Irrelevant Observing; W: Wait; N: No Wait; C: Control*
CHAPTER 4

RESULTS

Observing Response

Rate of Correct Response

The first research question concerns whether requiring an observing response to enhance control by relevant stimuli before answering a problem would increase the rate and percentage of accurate responding to mathematics facts. Figures 4.1 to 4.4 show that relevant observing did not produce consistently higher rates of correct responding across replications of the four experimental conditions for most of the 8 participants. Relevant Observing produced the highest rates of responding for 13 times during assessment sessions (Figures 4.1 and 4.3) and 4 times during choice sessions (Figures 4.2 and 4.4). In addition, mean rates of correct responding during Relevant Observing conditions were the highest only for Donna (M= 4.23), Henry (M= 7.53) and Daisy (M= 1.92), during assessment sessions. During choice sessions, mean rates of correct responding during Relevant Observing were never the highest. Finally, mean rates of correct responding during Relevant Observing were the lowest for Anna (M= 3.47) and Daisy (M= 1.2) during choice sessions.
When only Relevant and Irrelevant Observing performances were compared, Relevant Observing conditions produced higher rates of responding in 15 of the 33 assessment sessions (M= 4.06, range, 1.94 to 9.71) and in only 10 of the 30 choice sessions (M= 3.71, range, 2.13 to 6.06) across the 8 participants. Response rates during Irrelevant Observing conditions averaged 4.15 during assessment sessions (range, 1.24 to 9.81) and 4.99 during choice sessions (range, 1.85 to 12.89).

**ADHD vs. NonADHD**

Figures 4.1 to 4.4 show that the rates of correct responding during Relevant Observing across replications of the four experimental conditions for participants with and without ADHD. During assessment sessions (Figures 4.1 and 4.3), Relevant and Irrelevant Observing conditions produced the highest rates of responding six and seven times, respectively, out of 16 opportunities for participants without ADHD and seven and six times out of 17 opportunities for participants with ADHD. During choice sessions (Figures 4.2 and 4.4), Irrelevant Observing was the condition that produced the highest rates of responding most of the time (six and three times) for participants with and without ADHD respectively. In addition, analysis based on the mean rates of correct responding showed that 3 of the 4 participants with ADHD, but none of the participants without ADHD, emitted the highest rates of responding during Relevant Observing.
Figure 4.1. Number of correct responses per minute across Observing and Control conditions during assessment sessions for students without ADHD.
Figure 4.1 Continued

CORRECT RESPONSES PER MINUTE

Heather
(No ADHD)

Donna
(No ADHD)

- Relevant
- Irrelevant
- Wait
- No Wait

CONDITIONS

68
Figure 4.2. Number of correct responses per minute across Observing and Control conditions during choice sessions for students without ADHD.
Figure 4.2 Continued

Heather
(No ADHD)

Donna
(No ADHD)
Figure 4.3. Number of correct responses per minute across Observing and Control conditions during assessment sessions for students with ADHD.
Figure 4.3 Continued

CORRECT RESPONSES PER MINUTE

<table>
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<tr>
<th>CONDITIONS</th>
<th>Relevant</th>
<th>Irrelevant</th>
<th>Wait</th>
<th>No Wait</th>
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<td></td>
<td></td>
</tr>
<tr>
<td>Daisy (ADHD)</td>
<td></td>
<td></td>
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</table>
Alan (ADHD)

Dan (ADHD)

Figure 4.4. Number of correct responses per minute across Observing and Control conditions during choice sessions for students with ADHD.
CORRECT RESPONSES PER MINUTE

SESSIONS

Relevant
Irrelevant
Wait
No Wait

Henry
(ADHD)

Daisy
(ADHD)
When comparisons were made between only Relevant and Irrelevant conditions, Irrelevant Observing produced higher rates (10 sessions) more frequently than Relevant Observing (seven sessions) during assessment choices for participants with ADHD and equal number (eight sessions for each condition) for participants without ADHD. During choice sessions, Irrelevant Observing produced higher rates of correct responses for both groups (8 and 12 sessions for participants without and with ADHD, respectively) when compared to the Relevant Observing conditions that produced higher rates in only five sessions for participants with and without ADHD.

**Accuracy**

Similar to the data on rate of correct responding, Figures 4.5 to 4.8 show that relevant observing did not produce consistently higher percentages of correct responding across replications of the four experimental conditions for any of the 8 participants. Relevant observing conditions produced the highest percentage of correct response in only nine assessment sessions (see Figures 4.5 and 4.7) and one choice session (see Figures 4.6 and 4.8). More specifically, Relevant Observing produced the highest percentage of correct responses in two out of four assessment sessions for Denise, Heather and Henry, in two out of five for Dan, and in one out of three for Donna. During choice sessions, Relevant Observing produced the highest percentage for Daisy only in one session. Finally, identical optimal performance (100 % correct) between Relevant and one or more conditions occurred three times during assessment sessions and 13 times
during choice sessions. During choice sessions, tied scores occurred three times for Anna, Denise, and Dan, and one time for Heather, Donna, Alan, and Daisy.

When comparisons were made between Observing conditions separately, Relevant Observing produced higher percentages of correct responses in 13 (M = 94 %, range, 83 to 100%) of the 33 assessment sessions and in 4 (M = 96.1 %, range, 84.6 to 100%) of the 30 choice sessions. Performance was undifferentiated (M = 100%) between these two conditions in 3 and 11 assessment and choice sessions, respectively.

Delay Aversion

Rate of Correct Response

The second research question concerned the impact of delay aversion on the rate and percentage of accurate responding to mathematics facts. Figures 4.1 to 4.4 show that Wait did not produce consistently higher rates of correct responding across replications of the four experimental conditions for any of the 8 participants. Mean rates of correct responding during Wait conditions was the highest only for Dan (M = 1.90), during assessment sessions (see Figures 4.1 and 4.3) and for Heather (M = 5.26) and Daisy (M = 1.78) during choice sessions (see Figures 4.2 and 4.4). In fact, mean rates of correct responding during Wait conditions were the lowest for (a) Anna (M = 2.17), Heather (M = 3.87), Donna (M = 3.62), Alan (M = 2.56), Henry (M = 5.09), and Daisy (M = 1.34) during assessment sessions; and (b) Denise (M = 2.80), Alan (M = 3.86), and Henry (M = 6.19) during choice sessions.
When comparisons were made between only Wait and No Wait conditions, results indicated that No Wait conditions produced consistently higher rates of correct responding (M= 4.16, range 1.21 to 8.57) than Wait conditions (M= 2.63, range 1.4 to 5.91). Rates of correct responding were higher under No Wait for 20 of the 32 assessment sessions and 20 of the 29 choice sessions. More specifically, rates of correct responding during No Wait conditions were higher than during Wait in: (a) four out of five opportunities for Alan, and out of four for Henry, (b) three out of four opportunities for Heather, and out of three for Anna, and (c) two out of five opportunities for Denise, and out of three for Donna and Daisy during assessment sessions. During choice sessions, rates of correct responding during No Wait were the highest in: (a) four out of five opportunities for Denise and Alan, and out of four for Henry, (b) two out of four opportunities for Anna and Dan, and out of three for Heather, (c) one out of three opportunities for Daisy, out of one for Donna.

**ADHD vs. NonADHD**

Figures 4.1 to 4.4 show that the rates of correct responding across replications of the four experimental conditions for participants with and without ADHD. During assessment sessions (see Figures 4.1 and 4.3), control conditions (Wait and No Wait) produced the highest rates only one and two times, respectively, out of 16 opportunities for participants without ADHD, and three and one times out of 17 opportunities for participants with ADHD. During choice sessions (see Figures 4.2 and 4.4), rates for participants with ADHD differed more significantly from the ones without ADHD. No
Wait conditions produced the highest rates most of the time (8/16 opportunities) for participants without ADHD. This was double the number of times produced by the condition with the second best rates (Wait) which produced the highest rates only 4/16 opportunities. For participants with ADHD, Wait and No Wait conditions produced the highest rates equal times (4/17 each). In addition, analysis based on the mean rates of correct responding showed, that one participant with ADHD (Dan) emitted his highest rates during assessment, and another (Daisy) during choice Wait sessions. Wait produced the lowest rates of correct responding for 3 participants with ADHD (Alan, Henry, and Daisy), and 3 without ADHD (Anna, Heather, and Donna), during assessment sessions. During choice sessions, lowest rates during Wait were produced for 2 participants with ADHD (Alan and Henry) and one without ADHD (Denise).

When comparisons were made between Control conditions (i.e. Wait and No Wait) during assessment sessions, No Wait produced higher rates of correct in 10/16 sessions for participants without ADHD and 10/16 sessions for participants with ADHD. Wait conditions produced higher rates in only five and seven sessions for participants without and with ADHD, respectively. During choice sessions, No Wait produced higher rates of correct responses for 9/16 sessions for participants without ADHD and for 11/17 sessions and with ADHD. Wait conditions produced higher rates in four and five sessions for participants without and with ADHD, respectively.
Accuracy

Figures 4.5 to 4.8 depict the percentage of correct responses under Wait and No Wait conditions for participants with and without the diagnosis of ADHD. Differences based on comparisons between Control conditions showed that No Wait produced higher percentages of correct responses when compared to Wait in 17 (M = 93.52 %, range, 72 to 100%) of the 32 assessment sessions and in 2 (M = 83.35 %, range, 66.7 to 100%) of the 29 choice sessions. Performance was undifferentiated (M = 100%) between this two conditions in 21 of the choice sessions. More specifically, percentages of correct responding during No Wait conditions were higher than during Wait in: (a) four out of four opportunities for Heather, (b) three out of three opportunities for Donna, (c) two out of five opportunities for Anna and Alan, and out of three for Denise and Daisy, and (d) one out of five opportunities for Dan, and out of four for Henry during assessment sessions. During choice sessions, percentages of correct responding during No Wait were the highest in one out of two opportunities for Dan, and out of one for Daisy. Identical scores occurred four times for Alan and Henry, three times for Denise, Heather, and Dan, and two times for Anna, and Daisy.
Figure 4.5. Percentage of correct responses across Observing and Control conditions during assessment sessions for students without ADHD.
Figure 4.5 Continued

PERCENTAGE OF CORRECT RESPONSES

Heather
(No ADHD)

DONNA
(No ADHD)

CONDITIONS
Figure 4.6. Percentage of correct responses across Observing and Control conditions during choice sessions for students without ADHD.
Figure 4.6 Continued

Heather
(No ADHD)

Donna
(No ADHD)
Figure 4.7. Percentage of correct responses across Observing and Control conditions during assessment and choice sessions for students with ADHD.

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Figure 4.7 Continued

The figure shows a bar graph comparing the percentage of correct responses between Henry and Daisy under different conditions. Henry is represented by bars in black, while Daisy is represented by bars in white.

- **Conditions** include Relevant, Irrelevant, Wait, and No Wait.
- **Henry** (ADHD) consistently shows higher percentages of correct responses, especially under the Relevant condition.
- **Daisy** (ADHD) also shows a pattern of higher percentages under the Relevant condition, but the overall trend is slightly lower compared to Henry.

The graph provides a visual representation of how the participants performed under the specified conditions.
Figure 4.8. Percentage of correct responses across Observing and Control conditions during assessment and choice sessions for students with ADHD.

Continued
Figure 4.8 Continued

PERCENTAGE OF CORRECT RESPONSES

SESSIONS

Henry
(ADHD)

Daisy
(ADHD)
Choice

The third purpose of the study was to examine participants’ preferences for conditions. Only 2 participants showed an exclusive preference for a particular condition; Henry chose relevant observing and Donna chose no wait during all choice sessions. (See Figures 4.9 and 4.10). Relevant observing was also preferred over the other conditions (i.e., percentage of choice higher than 50) two out of four times for Heather. Denise showed preference (M= 41.29) for No Wait in five choices when compared to choices towards Wait (M= 6.03). All other participants showed indifference regarding the conditions by distributing their choices almost equally across conditions.

Latency during MTS versus Accuracy in Mathematics Problems

Data were also analyzed in respect to mean latencies during matching to sample that lead to correct and incorrect responses on the mathematics problems during Relevant Observing assessment sessions (See Figure 4.11). Overall, results showed that the mean time spent in seconds in the presence of the relevant stimuli during the identity matching of the Relevant Observing conditions was slightly shorter before the occurrence of accurate responses (M= 7.01 , range, 5.47 to 8.91) than before the occurrence of inaccurate responses (M= 7.49, range, 5.11 to 9.75) on the mathematics problems. Individual analysis showed, however, that the mean time spent in seconds in the presence of the relevant stimuli during the identity matching before the occurrence of accurate responses was higher for 3 participants (Anna, Donna and Alan). More specifically, Anna, Denise, Heather, Donna, Dan, Alan, Henry and Daisy spent on average approximately
6.62, 5.70, 5.55, 6.87, 8.91, 8.61, 5.47, and 8.33 seconds, respectively, in the presence of the relevant stimuli during the MTS task before emitting a correct response on the mathematics problem and 5.11, 7.40, 5.88, 5.51, 9.36, 7.73, 9.75, and 9.18 seconds, respectively, before emitting an incorrect response on the mathematics problems.
Figure 4.9. Percentage of choice across Relevant Observing, Irrelevant Observing, Wait and No Wait conditions for students without ADHD.
Figure 4.10. Percentage of choice across Relevant Observing, Irrelevant Observing, Wait and No Wait conditions for students with ADHD.
Figure 4.10 Continued

Henry (ADHD)

Daisy (ADHD)

- Relevant
- Irrelevant
- Wait
- No Wait

Percentage of Choice

Choice Sessions

93
Figure 4.11. Mean latency in seconds during matching to sample that lead to correct and incorrect responses on the mathematics problems during Relevant Observing assessment sessions.
Overall, the results indicate that rates of correct responding on mathematics facts increased for all participants across sessions for all conditions. No condition in particular, however, consistently produced higher rates of responding compared to the other conditions. There are two main possible interpretations for the lack of consistent results and for the overall increase in performance.

First, research has indicated that there is a high positive correlation between performance and performance feedback, especially in children with ADHD (Craig & Holland, 1970; Sherman & Anderson, 1980). In the current study, feedback was given immediately upon completion of each mathematics problem in all conditions. The immediate reinforcement for correct responses might have increased overall attention to the discriminative stimulus and consequently enhanced performance across conditions.

This possibility is also supported by findings in basic research with observing responses. These findings suggest the importance of the value of the conditioned reinforcer on the occurrence of observing/attending (Case & Fantino, 1981; Case et al., 1985; Gaynor & Shull, 2002; Shahan, 2002). They suggest that observing responses are maintained by the production of a stimulus that is correlated with reinforcement. In the
current study, observing responses during the Relevant Observing condition were frequently paired with reinforcement. It is possible, therefore, that observing responses were strengthened and may have generalized to the other conditions.

Second, small differences in rates of correct responding between conditions (often less than one problem per minute) might have been an artifact of the length of the sessions. Differences might have been more apparent with longer sessions that provided more opportunities to solve more problems.

There are also several possible explanations for the finding that a relevant observing response did not consistently increase the rate and percentage of accurate responding to mathematics facts. First, the Relevant Observing condition was designed to increase performance that was deficient due to lack of stimulus control by the relevant stimuli. However, the high percentages of correct responding suggest that performance deficits may have been attributable to fluency rather than to inattention to relevant properties of the problem stimulus. This possibility is supported by the overall increase in rate of correct responding across conditions; practice was the only variable that could have affected responding across all conditions in the same manner. In fact, some studies suggest that 10 minute drills with immediate feedback (similar to the procedures used in the current study) are an effective means of increasing fluency in mathematics facts (Hayter, Scott, McLaughlin, & Weber, 2007; Miller, Hall, & Heward, 1995; Miller, & Heward, 1992). Finally, the analysis based on latency of responses during the identity MTS strengthens conclusions about the role of fluency on responding to mathematics problems. According to findings in the conditional discrimination literature, there should
be a correlation between time in the presence of the relevant stimulus and performance (e.g., Berryman, Cumming & Nevin, 1963; Roberts, 1972; Sacks, Kamil & Mack, 1972). However, the data analysis conducted based on latency showed that increased time in the presence of the relevant stimulus was not correlated with higher rates of correct responding. This finding suggests that control by the relevant stimulus was not the (main) reason for the low rates of responding.

Second, increasing control by ‘the relevant stimuli’ might not have focused attention on the particular relevant stimuli that failed to control responding. Informal observations during data collection suggested that inattention to numbers rather than to the operations targeted by the observing response were the cause for the few errors committed. In addition, for 3 of the participants (AB, AN and DW) all types of problems were formed by only one type of operation (i.e., addition). Thus, attention to the mathematics operation should not cause most of the errors. Future research should use an error analysis to identify the particular stimulus that fails to control responding.

Results of the study suggest that delay aversion did have an impact on the rates of accurate responding to mathematics facts. No Wait conditions produced higher rates of correct responding than Wait conditions in 20 of the 32 assessment sessions and 20 of the 29 choice sessions. In addition, when Wait conditions were compared with the other three conditions, mean rates of responding during Wait were the lowest for 6 participants during assessment sessions and for 3 participants during choice sessions. These results partially support the hypothesis that performance of children with ADHD is strongly affected by delay aversion. Nevertheless, the fact that No Wait also produced higher rates
of responding for the participants without the diagnosis of ADHD fails to support the hypothesis that participants with ADHD were more delay averse than those without the diagnosis.

Although differences between Wait and No Wait were noticeable, these differences might have not been as large as expected, because of unintended effects during the Wait conditions. Informal observations suggested that participants typically used the wait interval to make the computations necessary to answer the problem, such that the answer could be entered as soon as the wait period elapsed. This could have minimized the aversiveness of the imposed delay, as well as decreased the delay to reinforcement once a response was enabled. This suggestion is supported by studies that increased self-control in children with disabilities by including intervening activities during delays (Dixon & Holcoumb, 2000; Dixon, Rehfeldt, & Randich, 2003; Mischel, Ebbesen, & Zeiss, 1972)

A possible modification to avoid minimizing the aversiveness of the wait condition would be the use of the operation symbol alone to signal the beginning of the Wait trials instead of the presentation of the entire problem. This would still allow the participants to observe the relevant stimuli before the problem is presented (in both Wait and Relevant Observing conditions), but without the benefit of using this time to solve the problem. For participants who used paper and pencil to solve the problems during the wait time, a more parsimonious modification would be not allowing the use of these materials.
Finally, it is possible that the delay interval for the Wait condition was too short to be perceived as aversive. Intervals were calculated based on the mean latency to respond during the identity matching of the Relevant Observing condition. Using longer wait times in future research might make differences in the impact of delay for participants with and without ADHD more prominent.

Results of the present investigation have several implications for the design of future research. First, regardless of the suggestions concerning the pivotal impact of delay aversion on the behavior of children with ADHD, the current investigation did not find that delay aversion had a greater impact on the performance of children with ADHD than it did on the performance of children without this diagnosis. In fact, this study suggests that in terms of performance, no consistent differences were found among these children. Future research should, however, include measures of behavioral control to better pinpoint the role of this variable on the behavior of children with ADHD and the relation between behavioral control and performance.

These findings should be interpreted with caution because in this study all participants with ADHD were receiving medication. The Multimodal Treatment of ADHD (MTA) Cooperative Group (1999) suggested that stimulant medication produces significant reductions in behaviors associated with ADHD. Thus, attention and impulsive problems of the participants in the current study might have been attenuated by medication, thereby masking the potential effects of the conditions relative to participants without ADHD.
Another implication for the design of future interventions for children with ADHD concerns the use of immediate and differential reinforcement for correct responses. Overall increase on performance in children with and without ADHD suggests that consistent reinforcement with short delays can produce boost performance to levels similar to the levels obtained by children without this diagnosis. Finally, this study is a first step in the direction of developing a valid and reliable tool to investigate and treat the effects of attention deficits in performance of mathematics facts by children with ADHD.

Despite the encouraging results regarding improvement in participants’ fluency with mathematics problems, one of the limitations of the study is its social and ecological validity. Regarding the study’s social validity, informal feedback from teachers and students suggested that the program was very well accepted and that similar interventions would be welcome in the future. However, formal assessment of the study’s social validity would have pinpointed specifically how the intervention was perceived in terms of goals, procedures and effects. Regarding the study’s ecological validity, this study was limited in systematically replicating classroom conditions that can be responsible for some of the problems encountered by children with ADHD. Future studies could, for example, simulate typical classroom distracters (e.g., noise) during the experimental task.

In summary, the current investigation was an initial step in investigating attention deficits in children with ADHD in an applied setting. By using a differential observing response to investigate the role and remediation of attention problems in children with ADHD, this study suggests a new conceptualization and promising methodology to
evaluate and address the problems in academic performance presented by these children. Currently, the majority of research in the area of interventions for children with ADHD has focused on issues pertaining to managing social behavior and appropriate classroom behavior (e.g., Pelham, Carlson, Sams, & Vallano, 1993; Purdie et al. 2002). Although academic failure is one of the most debilitating factors related to the disorder, DuPaul and Stoner (2004) emphasize the need to include academic success as a criterion for treatment evaluation.

In conclusion, this study may prompt other researchers to further examine the attention deficits of children with ADHD from a behavior analytic perspective. If future research validates a similar conceptualization and methodology as a reliable approach to investigate treatments for children with ADHD, it could substitute or at least supplement current assessment methods.
LIST OF REFERENCES


Multimodal Treatment Study for Children with Attention-Deficit/Hyperactivity (1999). A 14-Month Randomized Clinical Trial of Treatment Strategies for Attention-Deficit/Hyperactivity Disorder. *Archives of General Psychiatry, 56*, 1073-1086.


APPENDIX A

PARENT RECRUITMENT LETTER
February 20, 2008

Dear Parent/Guardian:

My name is Lilian and I am a doctoral candidate in Special Education at The Ohio State University. A requirement of completing my course of study is to conduct a research project under the supervision of my faculty advisor Dr. Nancy A. Neef, Professor in the College of Education and Human Ecology. This letter is being provided to you to explain my research and to ask your permission to include your son/daughter in my project. The following is a description of the study I plan to conduct and an explanation of your rights.

The study will examine factors that affect the performance of children with and without a diagnosis of Attention Deficit Hyperactivity Disorder (ADHD). To look at this, we will be using a computer-based assessment in which children can earn points exchangeable for rewards (e.g., small toys, stickers, or snack items which they choose) for completing mathematics problems within their capabilities. The assessment sessions take about 10-20 minutes to complete and would be conducted 3 to 5 days per week over a 3 to 12 week period. All of the sessions will occur during the school day. After we have obtained results from the assessment, we will share the information with you and your child’s teacher in an effort to develop and evaluate practical academic interventions to foster attending during classes and increased learning of the curriculum.

The computer-based assessment poses no risk to your child. The benefits to your child include practice working on mathematics problems. Your child’s identity will remain anonymous should we use the information in any reports, presentations, or publications. Participation in this study is voluntary; you or your child will be free to withdraw his or her participation at any time without prejudice or penalty.

Attached are two copies of the research consent form. By signing this consent form you are granting permission for your child to participate in this research project. You should return a signed copy of the form and keep the second copy for your records. Please return forms ASAP.

If you have any questions regarding this research or your rights related to participation in this research, please feel free to call/e-mail me at (614) 352-7559, rodrigues.10@osu.edu, or call Dr. Nancy Neef at (614) 688-8107. If you have questions about your son’s/daughter’s rights as a research participant, you can call the Office of Research Risks and Protection at (614) 688-4792. Thank you for your cooperation.
APPENDIX B

INFORMED CONSENT
CONSENT FOR PARTICIPATION IN RESEARCH

I give consent for my child, ___________________________________, to participate in research entitled: The role and remediation of attention deficits in performance of mathematics facts by children with ADHD being conducted by Nancy A. Neef, Ph.D., Principal Investigator, and her authorized representative, Lilian C. Rodrigues, MS. The intention of this study is in fulfillment of course requirements of a Doctoral degree program at The Ohio State University.

The purpose of the study, the procedures to be followed, and the expected duration of my child’s participation have been described to me. Possible benefits of the study have been described, as have alternative procedures, if such procedures are applicable and available. I acknowledge that I have had the opportunity to obtain additional information regarding the study and that any questions I have raised have been answered to my full satisfaction. Furthermore, I understand that my child is free to withdraw consent at any time and to discontinue participation in the study without prejudice to my child.

Finally, I acknowledge that I have read and fully understand the consent form. I sign it freely and voluntarily. A copy has been given to me. If any further questions arise I may contact the researcher at (614) 352-7559 to gain additional information. If I have questions about my rights as a research participant, I can call the Office of Research Risks Protection at (614) 688-4792.

_________________________________________      _________________________
(Person authorized to consent for participant)                             (Date)

______________________________________________________________________
(Principle Investigator or representative)                                      (Date)

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APPENDIX C

SCHOOL LETTER OF SUPPORT
To Whom It May Concern:

Lilian Rodrigues will be conducting research for her Doctoral dissertation in our school, Como Elementary School, where I am the principal. I have received the information regarding her proposed study entitled: The role and remediation of attention deficits in performance of mathematics facts by children with ADHD. I have also received a copy of the consent for participation, and I believe that the research study is in accordance with the standard teaching practices and in no way places students at risk. I understand the value of such research and give my permission and support for conducting this study in my school building.

Please feel free to contact me at (614) 365-6013 if any additional information is needed.

Sincerely,

Christopher Brady
Principal, Como Elementary
APPENDIX D

STUDENT DEMOGRAPHIC INFORMATION DATASHEET
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<td>Age</td>
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<tr>
<td>Grade</td>
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<tr>
<td>Race</td>
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<td>Gender</td>
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<th>Diagnoses</th>
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<tr>
<td>Meets DSM-IV Criteria for ADHD</td>
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<tr>
<td>Instrument Used for Diagnosis</td>
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<tr>
<td>Additional Diagnoses</td>
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<table>
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<th>Medication</th>
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<td>Medication Taken for Diagnoses</td>
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<tr>
<td>Type of Medication</td>
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<tr>
<td>Dosage of Medication</td>
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<td>Time Medication is Administered</td>
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<table>
<thead>
<tr>
<th>School</th>
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<tbody>
<tr>
<td>Record of Academic Difficulties</td>
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