THE INFLUENCE OF DEVELOPMENT AND METHYLPHENIDATE ON SELECTIVE ATTENTION IN CHILDREN WITH ATTENTION DEFICIT HYPERACTIVITY DISORDER

by

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Abstract

The present study investigated whether children with Attention Deficit Hyperactivity Disorder (ADHD) were less able to ignore distracters while attending to relevant information than children without ADHD. In addition, the influence of development and methylphenidate on selective attention were studied in a sample of children with ADHD. Twenty-four children with ADHD (12 younger, 12 older) and 32 Control children (14 younger, 18 older) were tested using a timed computer task. The task consisted of identifying target stimuli under seven distracter conditions [no distracter, visual distracters (meaningful or unmeaningful), auditory distracters (meaningful or unmeaningful), or visual and auditory distracters (meaningful or unmeaningful)]. Reaction times and accuracy were measured. Children with ADHD were less efficient on the selective attention task than children without ADHD. When children with ADHD were on methylphenidate they performed more efficiently on the task than they performed without medication. Also, when on methylphenidate younger children reached and even surpassed the efficiency of the control group. Older children in both groups were more efficient than younger children in each group. The implications of these findings are discussed and recommendations for future work are proposed.

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The Influence of Development and Methylphenidate on Selective Attention in Children with Attention Deficit Hyperactivity Disorder

Attention Deficit Hyperactivity Disorder (ADHD) has become a common childhood diagnosis in recent years. Prevalence figures range from 1 to 20 percent of the population, with the range of 3 to 5 percent being accepted by most professionals (e.g., Kelly & Ramundo, 1996). Children may be identified as having ADHD because of school problems, difficulty playing quietly, waiting a turn, completing an activity or listening. Although every child may display these behaviours at some time, children with ADHD exhibit these behaviours significantly more than their same age peers.

There is concern for individuals with ADHD and how the associated difficulties with attention are affecting educational experiences and thus, the learning process. In the classroom situation, children with ADHD may have more difficulty ignoring distractions than children without ADHD. If children with ADHD are, in fact, having more difficulty ignoring irrelevant stimuli it will affect their ability to perform the necessary tasks for successful completion of school work. If a child with ADHD is reading from a book, how may he/she be affected by the two children talking next to him/her? Or how does a bird sitting on the ledge outside the window affect his/her ability to read the material in the book? Given a diagnosis of ADHD, there are also concerns about treatment, including whether the benefits of medication outweigh potential negative side effects. This study was designed to create a better understanding of the effects that visual and auditory distracters have on the attentional abilities of a child with ADHD and how these effects change with age and methylphenidate (MPH) treatment.

Attention Deficit Hyperactivity Disorder

According to the Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition (DSM-IV; American Psychiatric Association, 1994), a diagnosis ADHD is based on developmentally inappropriate pattern of inattention, hyperactivity, and/or impulsivity, seen prior to the age of seven. This pattern of symptoms must lead to further difficulties in at least two settings (e.g., home, school) that result in interference in areas of social, academic, or occupational development (American Psychiatric Association, 1994).

The DSM-IV (American Psychiatric Association, 1994) describes the characteristics of inattention, hyperactivity, and impulsivity in the following manner. *Inattention* in children with ADHD is displayed by a frequent shifting in activities, including leaving activities uncompleted and avoiding activities that require sustained attention. They show poor organizational skills, are forgetful, and are easily distracted by irrelevant stimuli (American Psychiatric Association, 1994). *Hyperactivity* can be exhibited in many different ways by children with ADHD, such as the child's being fidgety in his or her seat, or being unable to remain seated. High rates of inappropriate running or climbing, excessive talking, and difficulty participating in quiet activities are also signs of hyperactivity (American Psychiatric Association, 1994). *Impulsivity*, as described in the DSM-IV (American Psychiatric Association, 1994) can be seen in the child's lack of patience, which may be shown by a child's blurting out answers prior to completion of a question and having difficulty waiting a turn. Thus, impulsivity might create social and academic difficulties for children with ADHD because they interrupt others, initiate conversations at inappropriate times and fail to listen to direction (American Psychiatric Association, 1994).

Characteristics of inattention, hyperactivity, and impulsivity usually worsen when a child with ADHD is in a group situation and lessen when the child is provided with one-on-one attention or in a situation with strict control (American Psychiatric Association, 1994). Also, the DSM-IV indicates that symptoms usually worsen when a child with ADHD encounters a task that requires sustained attention or mental effort or a task that lacks novelty and/or intrinsic appeal. The symptoms may lessen when the child is in a situation that is novel, interesting and/or provides frequent rewards for appropriate behaviours (American Psychiatric Association, 1994).

ADHD creates difficulties for the individual with the disorder, as well as for caregivers and educators. In addition to the attentional difficulties associated with ADHD, children with ADHD are frequently given comorbid diagnosis of Oppositional Defiant Disorder (ODD) or Conduct Disorder. ODD is characterized by the DSM-IV (American Psychiatric Association, 1994) as a pattern of behaviours that are negative, defiant, disobedient, and hostile toward authority figures. Conduct Disorder is characterized as a pattern of behaviours that violate societal norms and the basic rights of others (American Psychiatric Association, 1994).

It is believed that ADHD is not caused by a single factor, although the causes have not been well established. Wender (1987) indicated that the severity of ADHD can be influenced by an environment which lacks structure, clear rules and supervision but it is not environment or parental treatment of the child that causes the disorder. In other words, Wender (1987) suggests that ADHD is an issue of nature not nurture. It has been proposed that ADHD is a hereditary disorder (Parker & Gordon, 1992), a chemical imbalance in the brain (Shibagaki, Yamanaka, & Furuya, 1993) or an impairment to the frontal lobe of the brain (Wilkins, Shallace, & McCarthy, 1987). This chemical imbalance or impairment to the frontal lobe of the brain might produce underactivity in sections of the brain, which may result in attentional difficulties such as a decreased ability to focus attention and a lack of control over one's behaviours (Wender, 1987). A study by Lou, Hendriksen, and Bruhn (1984) found evidence to support the hypothesis of CNS underarousal in children with ADHD who exhibited decreased blood flow to the frontal lobes of their brain. In further support, MPH, a commonly prescribed medication for treatment of ADHD, was shown to increase blood flow to the frontal lobes and provide improvement for symptoms of ADHD (Lou et al., 1984).

From the diagnostic criteria it can be observed that children with ADHD would be expected to have difficulty with tasks requiring attention. There are, however, many different forms of attention and it is necessary to understand what components of attention provide difficulties for children with ADHD.

Attention

Researchers have focused on two major components of attention, sustained attention (e.g., Corkum & Siegal, 1993; Halperin, Wolf, Greenblat & Young, 1991; Harper & Ottinger, 1992) and selective attention (e.g., Carter, Krener, Chaderjian, Northcutt, Wolfe, 1995a; DeMarie-Dreblow & Miller, 1988; Halperin, 1991; Plude, Enns, & Brodeur, 1994; Satterfield, Schell, Nicholas, Satterfield, & Freese, 1990). Sustained attention is the ability to maintain attention over time whereas selective attention is the ability to attend to relevant information while ignoring irrelevant information.

Although the focus of this study is selective attention, a brief discussion of sustained attention is warranted to provide the ability to compare these two components of attention throughout the current study.

Sustained attention.

The Continuous Performance Test (CPT), originally designed by Rosvold, Mirsky, Sarason, Bransome and Beck in 1956 (Halperin, 1991), measures sustained attention and has become a widely used test for both research and diagnosis (e.g., Corkum & Siegal, 1993; Halperin, et al., 1991; Harper & Ottinger, 1992; Irwin & Mettelman, 1989; Lassiter, D'Amato, Raggio, Whitten, & Bardos, 1994). The task most commonly involves a child indicating the presence or absence of a target letter (e.g., "X") or a sequence of letters (e.g., "AX"), as single letters are flashed on a computer monitor at regular intervals. The visual task may utilize numbers or pictures rather than letters. The CPT can also be presented as an auditory task, requiring children to detect a target letter or number heard through headphones. Inattention and impulsivity are measured by analysis of errors of omission (targets missed) and errors of commission (false alarms), respectively.

A considerable amount attention research associated with ADHD has used the CPT to measure sustained attention. This work was reviewed by Corkum and Seigal (1993). They found the evidence to be fairly conclusive that children with ADHD have difficulty maintaining constant arousal and therefore do not perform as well on sustained attention tasks as children without ADHD (Corkum and Seigal, 1993). Sustained attention, however, may be confounded with motivation and boredom and thus tasks such as the continuous performance test may not necessarily represent the way we process information regularly.

Selective attention.

Selective attention is the process of selecting what is relevant from our environment and thus, is important to process further (Halperin, 1991). For example, when children are in school and are attempting to read a book at their desks, they need to attend to what they are reading while they ignore movement (visual distracters) or talking (auditory distracters) within the classroom. It is a normal response for all children and adults to take time to ignore distracters in their environment. To what extent and how quickly individuals can ignore these distracters may be the result of a number of factors including their age, state of arousal, visual processing abilities and the presence of any attentional difficulties.

Several methods have been used to study selective attention such as the Stroop colour-naming task, speeded classification tasks, and the flanker task. Reaction times, accuracy and sometimes event-related potentials are used to measure attention. The Stroop Colour-Naming task involves reading a word (e.g., *green*) that is printed in an incongruent colour of ink (e.g., red) or having the child name the colour of the word. In this task the child must ignore the ink colour or the colour name to respond accurately. A speeded classification task involves sorting mutidimensional stimuli according to a single dimension as quickly and accurately as possible (Tarawoski, Prinz, & Nay, 1986). Thus, the presentation of task-irrelevant information (i.e., multidimensions) allows for the assessment of interference effects by comparing sorting speed for cards with none, one, or multiple distracters. Eriksen and Eriksen (1974), developed a flanker task to investigate selective attention. The task involved presenting a target item in the center of a display either alone or flanked to the right and left by distracters of various types. Although developed to study adults, this paradigm has more recently been applied to study children (Enns & Akhtar, 1989). In general, studies conducted using these methodologies report decreases in performance in the presence of distracters. Several factors influence the extent of this decrease, however, including age and the nature of the distracters present.

In order to understand the impact of childhood ADHD on selective attention, it is necessary to understand how these abilities develop in children without ADHD. Research studying the development of attention will be reviewed, followed by a review of research on selective attention abilities of children with ADHD.

Developmental Trends in Selective Attention

Developmental studies of selective attention have consistently shown that as age increases interference effects lessen (e.g., DeMarie-Dreblow & Miller, 1988; Lane & Pearson, 1982). These results have been consistent across various research methodologies. For example, Well, Lorch, and Anderson (1980) studied interference effects using speeded classification tasks. Their results indicated interference effects declined significantly with increased age. As well, selective attention strategies have been found to improve with age. DeMarie-Dreblow and Miller (1988) examined the use of strategies that were child-controlled and experimenter-controlled. They found an improvement with age in the use of both strategy types. This increase in ability to use strategies to filter distracters leads to an increase in efficiency on selective attention tasks.

More recently, Bedi, Halperin, and Sharma (1994) collected a number of measures for 73 children (mean age = 114.7 months) to determine if distractibility was modality-specific. The following measures were collected: the Revised Conners Parent's Questionnaire (CPQ), the Conners Teacher's Questionnaire (CTQ), the Weschler Intelligence Scale for Children- Revised (WISC-R), the Wide Range Achievement Test - Revised (WRAT-R), the CPT, the Auditory Focused Attention Test (AFAT), and the Visual Focused Attention Test (VFAT). The AFAT and VFAT include both a no-distracter and a distracter condition. The results suggested that distractibility was modality-specific and that the scores that were obtained for distractibility in visual and auditory tests were unrelated. Thus, a deficit in one modality did not mean a deficit would also be present in the other modality. Using the scores from the CPQ and the WISC-R, Bedi et al. (1994) determined that auditory distractibility was associated with cognitive functioning and visual distractibility was associated with teacher behaviour ratings and inattention on the CPT.

Researchers have also begun to employ selective attention tasks such as the flanker task (Eriksen & Eriksen, 1974) to study development (e.g., Enns & Akhtar, 1989). This work will be reviewed in more detail because it employs similar methods to the present study. Enns and Akhtar (1989) tested children (aged 4, 5, and 7 years) and adults (20 years-old) on a task which isolated several sources of interference in selective attention. They employed Eriksen and Eriksen's (1974) flanker task to assess the impact of various distracter conditions. The seven distracter conditions were made up of two response categories and a no response category. Items that could be either targets or distracters were in the response category whereas items that could be distracters but were never targets were in the no response category. The first response category consisted of geometric shapes that contained line intersection and line termination (x and +), and the second response category consisted of geometric shapes that contained the feature of closure and did not posses the characteristics of the first response category (□ and O). The no response category consisted of geometric shapes that were never part of the response category but were used as distracters in some conditions (✳ and Δ).

Participants completed one block with no-distracters (e.g., +) to determine baseline responding. The other six conditions were mixed within blocks: (1) no-distracters (e.g., +), (2) distracters identical to the target (e.g., + + +), (3) distracters that were from the same response category as the target (e.g., × + ×), (4) distracters from a different response category than the target (e.g., □ + □), (5) distracters that were similar to the target but from the no response category (e.g., ✳ + ✳), and (6) distracters that were dissimilar to the target and from the no response category (e.g., Δ + Δ). Participants were required to make a forced choice recognition response. Reaction time and accuracy were measured.

The study by Enns and Akhtar (1989) used distracters that were meaningful and unmeaningful. Meaningful distracters usually cause a strong association to be made between the target and the response and therefore, meaningful distracters required inhibiting a response opposite to the target. Unmeaningful distracters are irrelevant to the target and should not require the same inhibition for response. Thus, for a distracter to be meaningful it must have some connection to the target in the present trial. For example, the distracters may be the target in other trials and therefore, an association may be made (i.e., the distracter is associated with being a target) that would increase the probability that the distracter may cause the opposite response than the one required. This may cause a decrease in performance because the distracters would require greater inhibition than distracters that would never be presented as a target. Younger children have been shown to have more difficulty inhibiting responses than older children (Plude et al., 1994).

The distracter conditions in the study measured five potential sources of interference. First, the difference between the block with no-distracters and the no-distracter condition in the mixed block indicated the amount of interference (proactive and retroactive) caused by the presence of distracters on some trials. Results indicated that the expectation of and preparation for distracters created a large source of interference, and this interference decreased as children became older. This suggests that preparing to inhibit distracters causes an increase in response time even when the item does not contain distracters. A second potential source of interference was indicated by the difference between the no-distracter condition and the identical distracters condition. The difference was used to determine if increasing the number of items to be encoded caused interference. Results indicated interference in performance decreased with age. Encoding interference was also measured by looking at the type of distracters (difference between the condition with distracters from the same category as the target and the condition with distracters identical to the target). Findings suggested that for children the increase in items to process and inhibit causes interference but that the interference in performance does not increase because of the type of distracters. There were no differences in performance found for the children when the difference was compared between the condition with distracters from a different category than the target and the condition with distracters from the same category as the target. Differences were not found between conditions with similar and dissimilar categories of distracters.

Results of the study by Enns and Akhtar (1989), as well as a study by Fox (1994), indicate that the interference experienced by children and adults follow a similar pattern, but as age increases, individuals are faster and more accurate at completing the task. Thus, distracters create interference for all ages but younger children experience more interference from distracters.

ADHD and Selective Attention

The DSM-IV (American Psychiatric Association, 1994) states that individuals with ADHD "are easily distracted by irrelevant stimuli and frequently interrupt ongoing tasks to attend to trivial noises or events that are usually and easily ignored by others" (p.79). Thus, according to the DSM-IV (American Psychiatric Association, 1994), children with ADHD should show deficits in selective attention, as well as sustained attention. Research on deficits in selective attention in children with ADHD has not yet been able to provide conclusive results. Some studies have found a deficit in selective attention (e.g., Carter et al., 1995a; Ceci & Tishman, 1984; Satterfield et al., 1990) while other studies have not (e.g., Landau, Lorch, & Milich, 1992; Tarnowski et al., 1986). Some of this work will be reviewed below.

Studies have shown that children with ADHD perform more poorly when task demands are high. Hooks, Milich, and Lorch (1994) found that the presence of irrelevant stimuli in speeded classification is not demanding enough to demonstrate a selective attention deficit in children with ADHD unless sorting time is considered. The results of the study by Hooks et al. (1994) indicated an increase in time required for sorting, for both ADHD and control groups, when irrelevant information was added. Boys with ADHD improved their sorting time with number of trials and habituated to irrelevant stimuli as did the control group. The boys with ADHD, however, were slower at these tasks than the controls, suggesting that the children with ADHD experienced more difficulty with the selective attention task than did the control group.

A study by Ceci and Tishman (1984) showed that when task demands were high, children with hyperactivity performed significantly worse on selective attention tasks than the controls but when demands were low they performed much better than the control group, while the control group remained constant across tasks with high and low demands. In this study, children without ADHD were relatively unaffected by task demands. Thus, children with ADHD appear to show deficits in selective attention only when processing demands of the task are high, creating a situation in which the children's attention is spread too widely to process the information efficiently. When task demands are low, however, there is time for the child to process the entire display efficiently.

Researchers have also examined the role that the nature of distracters may play in determining selective attention in children with ADHD. The impact of distracters on the short-term recall of 11 children with ADHD and 8 children without ADHD (mean age = 8.7) was studied by Higginbotham and Bartling (1993). Within the study there were visual (person walking through the room), auditory (book dropping outside the door), and a combination of visual and auditory distracters (person walking through the room and rustling papers), as well as a no-distracter condition. The experimenters read sentences that the children had to repeat. The children with ADHD did not perform as well on the task as did children without ADHD. In addition, the children with ADHD did not show a difference between different distracters and were more distracted than children without ADHD even in the absence of a distracter. Higginbotham and Bartling (1993) suggested that not only are the distracters affecting the performance of a child with ADHD when the distracters are present but the distracters may be impairing the child's ability to attend following distraction.

Attentional difficulties, such as impulsiveness and inattention in children with ADHD have been linked with impairment of frontal lobe functioning (Barkley, Grodzinsky, & Dupaul, 1992; Wilkins, et al., 1987). The Stroop Colour-Naming Task is a common selective attention task that is a sensitive measure of frontal lobe functioning (Carter et al., 1995a). Carter et al. (1995a) studied 20 children with ADHD and 20 controls, utilizing a computerized trial-by-trial version of the Stroop task. Results indicated that the distraction caused by task-irrelevant information is more disruptive for children with ADHD. The children with ADHD took longer to name the colour of colour-incongruent words but they did not make more errors than control children, suggesting an information-processing deficit rather than errors from impulsive responding.

Event-related potentials have also been used to study selective attention in children with ADHD (Satterfield et al., 1990). A longitudinal study by Satterfield et al. (1990) found differences in the event-related potentials of boys with ADHD and controls. Boys with ADHD did not perform as well as boys without ADHD on a selective attention task where they were to attend to one of visual or auditory information while ignoring the other. The finding that "abnormally small P3b response amplitudes in the attended channel, rather than to abnormally large P3b responses in the ignored channel" (Satterfield et al., 1990, p. 896), suggests a deficit in selective attention may be due to insufficient processing of the relevant stimuli. In addition, children with ADHD were significantly less accurate than children without ADHD. Children with ADHD, however, did not differ significantly in reaction time from children without ADHD.

Pearson, Yafee, Loveland, and Norton (1995) studied covert attention in children with and without ADHD. They described covert attention as a primary component of selective attention that required an individual to shift his or her attention from one location to another, independent of eye movements. This shift in location may be one of the causes for longer response times during a selective attention task. As more control is gained in reducing this shift in attention the efficiency of selective attention increases. Results of the study by Pearson et al. (1995) suggested that children with ADHD, as well as control children demonstrated orienting responses to location cues. The children with ADHD, however, showed inconsistencies in facilitation and inhibition associated with cues. Children with ADHD, and children without ADHD, were faster when the location of the cue was valid, relative to neutral and invalid cues. Children with ADHD, however, were inconsistent in responding when there was invalid or neutral cues. Contrary to expectations, reaction times for invalid trials were not consistently found to be longer than reaction times for neutral cues. Thus, children with ADHD found the absence of a cue to be worse than an invalid cue at times. Pearson et al. (1995) interpreted these results to be inconsistent with the idea that children with ADHD have attention skills that are developmentally immature. They suggest that some components of attention may show developmental immaturities while other components do not. They only used one age group (mean age: 10 years, 7 months) and recommended that future studies should compare and contrast older and younger children with and without ADHD.

Not all studies show deficits, however. Landau et al. (1992) studied the attention of 19 boys with ADHD as compared to 20 boys without ADHD on a task that required them to watch a television program and answer questions concerning the content. They completed this task twice, once with toys present and once without any toys present. Results indicated that with the presence of distracter toys, children with ADHD attended (visually) to the TV program a significantly smaller amount of the time than the children without ADHD. The groups did not differ when there were no toys present. Interestingly, although the children with ADHD attended less (i.e., did not look at the television as much as controls) to the program when toys were present, their recall of events on the show was not significantly different from the children without ADHD who were attending. The results of the study by Landau et al. (1992) indicated that the attentional abilities of children with ADHD are not necessarily less effective than children without ADHD, but that children with ADHD may share their attentional resources more widely.

Thus, results of previous studies do not provide conclusive evidence for a deficit in selective attention in children with ADHD. Some studies have shown deficits (Carter et al, 1995a; Ceci & Tishman, 1984) but others have not (Landau et al., 1992). Also, there has been little developmental work completed in the area of selective attention with children who have ADHD. The majority of selective attention studies on children with ADHD combine children of various ages into one group. Hooks, et al. (1994) tested children aged 7 to 12 years old in one group. Shibagaki et al. (1993) and Landau, et al. (1992) used a sample of children between 6 and 12 years old as one group. This practice is problematic because there is evidence that selective attention changes with development in normative populations (for review see Plude et al., 1994) and may therefore change in children with ADHD. More work on the development of selective attention in children with ADHD is needed.

The Effects of MPH on Attention

Amphetamines have been used to treat ADD since 1937 and MPH (Ritalin) has been in use since the early 1960's (Wender, 1987). Psychostimulant medication has become the most commonly utilized treatment for children with ADHD (Greenhill, 1992) and MPH has become the most commonly prescribed of the stimulant medications. Dupaul and Barkley (1990) suggest that one of the greatest benefits of MPH is that it maximizes the benefits that occur from treatments such as behaviour modification and academic tutoring. Examination of the effects of MPH have also become an important issue for the study of attention in children with ADHD. The effects of MPH on selective attention in children with ADHD have not yet been well established in the ADHD literature.

The use of MPH has been and remains a controversial issue in the treatment of ADHD. Consistent with the theory that an imbalance exists in the child's brain chemistry MPH, when given in an appropriate dosage, calms the child with ADHD and increases his or her attention span (Shibagaki et al., 1993). MPH is a stimulant medication that works by increasing the blood flow to the frontal lobe (Lou et al., 1984). Literature suggests, however, that there is a difference between the dosage of MPH that is effective for attentional purposes and the dosage that is effective for behavioural control (Carlson & Bunner, 1993). A study by Sprague and Sleator (1977) found that optimal cognitive performance occurred at a lower dose of MPH than did optimal social behaviour. Thus, in prescribing a dosage of MPH to a child there needs to be careful consideration given to both cognitive and social factors.

A study by Dalebout, Nelson, Hletko, and Frentheway (1991) examined selective attention by utilizing the Selective Auditory Attention Test (SAAT) with children with ADHD on (0.3-0.6 mg per kg of body weight) and off (placebo) MPH. They had 12 subjects in the ADHD group ranging in age from 7 to 8 years. The non-ADHD group consisted of 6 children between the ages of 6 and 8 years. In using the SAAT six coloured pictures are placed on a table in front of the child. The task requires the child to respond to 25 requests by pointing to the indicated picture. There are two subtests: (1) no-distracter and (2) distracter. In the no-distracter subtest the child only hears "show me____" whereas in the distracter subtest the child hears "show me___" while a short story is also being presented.

The results of the study by Dalebout et al. (1991) indicated that there was no main effect of group (between ADHD and control) and no main effect of drug (for the ADHD group). Thus, the children with ADHD responded similarly to the selective auditory attention task whether they were on medication or not. Improved performance, however, was found for all groups the second time that they performed the task. This study may not have shown any drug effect because the tasks were very simple and short (total= 8 minutes). Other studies have shown that when children are given MPH their attention increases, they are less impulsive and they become less easily distracted by irrelevant stimuli within a classroom allowing an increase in on-task behaviour and academic efficiency (DuPaul & Rapport, 1993; Malone & Swanson, 1993).

In a double-blind placebo controlled study, DuPaul and Rapport (1993) studied the effects of methylphenidate (5, 10, 15, and 20 mg dosages) on classroom behaviour and academic functioning. Thirty-one children with ADHD between the ages of 6 and 11 years were compared to a control group on teacher ratings, on-task behaviour, and academic performance. Results indicated that attention (on-task behaviour), academic efficiency and teacher ratings of classroom conduct all significantly improved when children with ADHD were on mid (10 or 15 mg) to high (20 mg) dosages of methylphenidate. The addition of medication improved the children with ADHD to a level similar to their peers in the control group on the studied measures.

Similarly, Malone and Swanson (1993) measured impulsivity in a double- blind placebo controlled study testing 26 children with ADHD between the ages of 6 and 13 years old and 14 children without ADHD between the ages of 6 and 11 years-old. Using a word matching task they found that the impulsivity of children with ADHD was reduced to a level similar to their peers without ADHD when they were taking MPH.

Although the developmental effects of MPH have not been studied with a selective attention task, there have been studies that examine the developmental effects of MPH. Barkley, Karlsson, Polland, and Murphy (1985) studied the interaction between the mother and child in children with ADHD while the children were on two different doses of MPH. The children were in one of five age groups: 5, 6, 7, 8, or 9 years old. The results did not show any age or dose effects in a free play condition but during a task condition both age and dose effects were found. During the task condition there was an increase in compliance and sustained attention with an increase in age and the higher dose of MPH was the only one of the two doses that was effective in producing changes. There was not an age by MPH interaction in this study. In a study by Whalen et al. (1987), however, MPH was shown to have different effects at different ages when measuring social behaviours on the playground. Both the 7 to 8 year-old children and the 9 to 11 year-old children showed a decrease in negative social behaviours when they were taking low doses of MPH as compared to the control but only the younger group showed more improvement when taking the high doses of MPH.

In summary, MPH has been shown to be effective at improving learning for children with ADHD (e.g., DuPaul & Rapport, 1993) but it is unclear what the effects of MPH are on selective attention (e.g., Dalebout et al., 1990). In some areas of research

MPH has been shown to have developmental effects (e.g., Whalen, et al., 1987) but not in other areas (Barkley et al., 1985). The developmental effects of MPH on selective attention have not yet been determined.

Present Study

Previous research on the impact of ADHD on selective attention has yielded inconclusive results. To investigate selective attention and its' development in the present study two age groups were studied: ages 6 to 8 years and ages 9 to 11 years. Previously, studies on selective attention in an ADHD population have collapsed different ages in to one group (e.g., Hooks et al., 1994; Landau et al., 1992). This practice is of concern because age differences have been found in studies of selective attention with normative populations and are most likely present in children with ADHD (Fox, 1994; Lane & Pearson, 1982).

Various studies have suggested that the nature of interference is contingent on the nature of the distracters (Bedi et al., 1994; Enns & Akhtar, 1989). Bedi et al. (1994) suggested that distractibility is modality-specific and Enns and Akhtar (1989) suggested that distractibility is dependent on the source of interference and whether the distracters are meaningful or unmeaningful to the target. To explore the role of various forms of visual and auditory distracters the task in the present study involved the presentation of various distracters from the visual modality, the auditory modality and a combination of both the auditory and the visual modality. Distracters in each modality condition were presented as meaningful and unmeaningful. Meaningful distracters were distracters that were also used as the target item on some trials whereas unmeaningful distracters were never used as targets.

Furthermore, the effect of MPH on selective attention tasks and whether or not these effects change with age are not known. In the present study, the effects of MPH were studied by comparing children with ADHD when they were on-MPH and off-MPH. The two age groups in this study allowed for examination of developmental effect which have been found in previous research on medication effects (Whalen et al., 1987). Also, the control group provided the ability to determine if MPH increased the performance of children with ADHD to the level of their same age peers. The development of selective attention in ADHD children and the impact of MPH on these effects have not been well documented within a single study.

A visual selective attention task similar to the task used by Enns and Akhtar (1989) was used. The task included conditions with either no-distracters, visual distracters (meaningful or unmeaningful), auditory distracters (meaningful or unmeaningful), or a combination of visual and auditory distracters (meaningful or unmeaningful). The computerized task involved responding to the picture of target stimuli (shirt or tie) located at the center of the computer screen. As a visual distracter, pictures of articles of clothing were located to the right and left of the target article of clothing. The names of non-target articles of clothing were presented through headphones as auditory distracters. Children with and without a diagnosis of ADHD were tested. The children with ADHD were tested off and on-MPH. Group comparisons were made on speed and accuracy of completing the selective attention task.

Hypotheses

Based on previous research findings and limitations the following questions were proposed and hypotheses made:

1. Do children with ADHD differ in selective attention ability from children without ADHD? The literature indicates that children with ADHD are more distractible than children without ADHD (Carter et al., 1995a; Ceci & Tishman, 1984; Pearson et al., 1995). Thus, children with ADHD should find it more difficult to ignore irrelevant information while trying to process and respond to the target information. Also, the task in the present study involved the presentation of distracters in a timed task, which was suggested by Ceci and Tishman (1984) to challenge the processing abilities of children with ADHD. Thus, children with ADHD were expected to show longer reaction times and decreased accuracy when compared to children without ADHD in the same age group.

2. Does MPH improve the performance of a child with ADHD on a selective attention task? It has been determined that MPH increases the level of arousal and thus sustained attention of children with ADHD but the effects of MPH on selective attention are unknown (Dalebout et al., 1991). MPH has been shown to improve the performance of children with ADHD in studies of on-task behaviour (DuPaul & Rapport, 1993). Also, MPH has been shown to reduce impulsivity in children with ADHD (Malone & Swanson,

1993). In the present study improvements in selective attention are expected in the on-MPH condition in comparison to the off-MPH condition.

3. Do developmental trends in selective attention differ for children with ADHD and children without ADHD? Developmental studies of children without ADHD show improvements in children's abilities with increasing age (Plude et al., 1994). It is unclear what the developmental trends are for children with ADHD. It was expected that the developmental trends would follow a similar pattern for children with and without ADHD. That is, both groups were expected to improve with age, although perhaps not at an equal rate.

4. Does MPH influence the developmental trend? MPH may improve the child's performance on the selective attention task while the children continue to show a similar developmental trend. As indicated in a study by Whalen et al. (1987), MPH may affect children of different ages to different magnitudes. Children with ADHD (on and off-MPH) and children without ADHD, however should show a decrease in reaction time and an increase in accuracy as age increases. Thus, although MPH is expected to improve the performance of children with ADHD this improvement may be of different magnitudes for different age groups.

5. Is visual selective attention impaired more by auditory or visual distracters or a combination of both? In the present study it was expected that children with ADHD would be more impaired by the introduction of visual distracters than the introduction of auditory distracters because visual distractibility is associated with hyperactivity and inattention

while auditory distractibility is associated with cognitive functioning (Bedi et al., 1994). Both groups, however, may find the visual distracters more distracting than the auditory distracters because the targets for this task were visual and thus, visual distracters would provide modality-specific disruption. Both groups were expected to show more interference when both visual and auditory distracters are presented on the same trial than when either the visual or auditory distracters are presented alone on a trial. It was expected that children with ADHD would show larger effects than children without ADHD in all three distracter conditions.

6. Do meaningful distracters create more interference than unmeaningful distracters? Meaningful distracters were distracters that were also used as the target item on some trials whereas unmeaningful distracters were never used as targets. It was expected that meaningful distracters would cause more interference than unmeaningful distracters because the meaningful distracters require an incompatible response whereas the unmeaningful distracters are irrelevant to the target (Enns & Akhtar, 1989). An incompatible response requires inhibiting a response to the distracter. Research suggests that children with ADHD have difficulty inhibiting (e.g., Malone & Swanson, 1993), therefore greater deficits are expected for the ADHD group than for the control group when an incompatible response is required.

Method

Participants

A visual attention task was completed by a sample of 56 children. Two groups of children participated in the study: an ADHD group and a control group that was matched to the ADHD group for age, socio-economic status, and a male to female ratio. The ADHD group consisted of 24 children recruited from a population of children between the ages of 6 and 11 years old who were undergoing treatment for a diagnosis of attention deficit hyperactivity disorder. The children were divided into two age groups: 12 children (10 male) in the younger age group (mean age = 7 years-5 months; SD = 0 years-11 months) and 12 children (10 male) in the older age group (mean age = 10 years-5 months; SD = 1 year-1 month). The children with ADHD were all receiving methylphenidate (MPH) and the diagnosis of ADHD was given following a battery of assessment tools. The children with ADHD were tested under two conditions: off-MPH and on-MPH. The off-MPH task condition was completed during regular prescribed breaks from the medication and was in no way dependent on the study. When tested on-MPH children had received their medication an average of 2 hours prior to testing and when tested off-MPH children had received their medication an average of 22 hours prior to testing. All children with ADHD (younger and older) were receiving 10 mg dosages of MPH either two or three times daily.

The control group consisted of 32 children. Fourteen children (11 male) made up the younger age group (mean age = 7 years-5 months; SD = 0 years-7 months) and 18 children (15 male) made up the older age group (mean age = 10 years-7 months; SD = 0 years-7 months). Teachers were requested to complete the Conners' Teacher Rating Scale-28 (CTRS-28; Conners, 1989) to ensure that children in the control group did not have attentional problems. Children who received T-scores of less than 65 on all of the subscales of the CTRS-28 (Conduct Problems, Hyperactivity, Inattentive-Passive and Hyperactivity Index) were included in the control group. Four children in the younger age group, and 3 children in the older age group obtained a score greater than 65 on at least one of these subscales and thus, were omitted from the analysis. To create a similar male to female ratio in the control group and the ADHD group a number of females in the control group (5 in the younger age and 10 in the older age) were randomly selected and omitted from the analysis. These 15 participants are not included in the 32 children described above.

Stimuli and Apparatus

For this study a computer-based selective attention task with visual and auditory distracters was created with Genexp v.1 software (Hamm, 1996). The millisecond timing routines were modified from Crosbie (1989), and the keyboard was monitored by the "KEYPRESSED" function in Borland Pascal 7.0 as opposed to the "READKEY" function to obtain ± 1 ms resolution for the reaction times (Brysbaert, 1990).

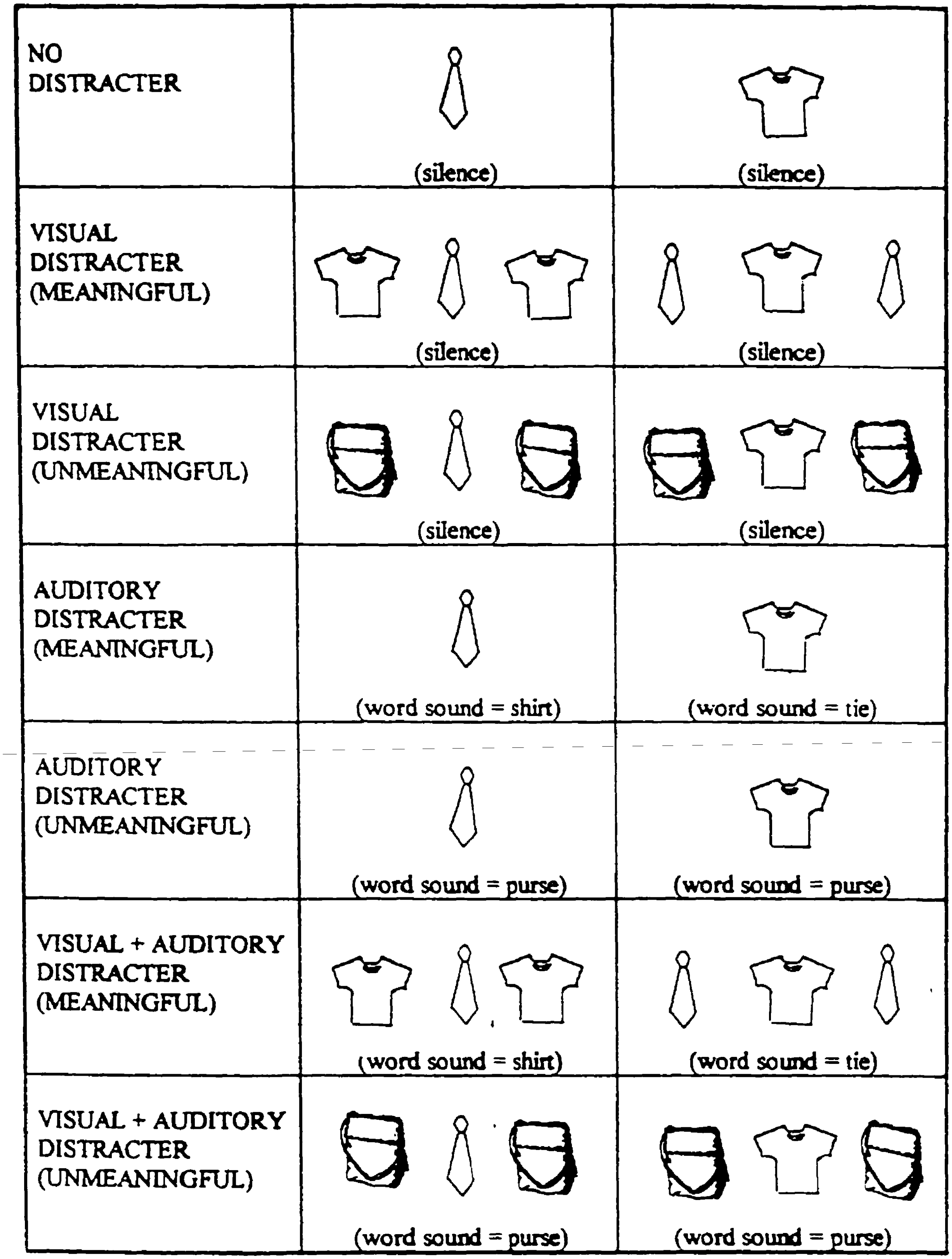
The stimuli included pictures of articles of clothing presented on the computer monitor and names of articles of clothing presented through headphones (see Figure 1). A picture of the target article of clothing (a shirt or a tie) was presented under several conditions: (1) alone (no-distracter condition), (2) in the middle of two response-incompatible distracter pictures (either ties or shirts) (meaningful visual distracter condition), (3) in the middle of two irrelevant distracter pictures (purses)(unmeaningful visual distracter condition), (4) with a response-incompatible article of clothing name (either tie or shirt) presented simultaneously through headphones (meaningful auditory distracter condition), (5) with an irrelevant article of clothing name (purse) presented simultaneously through headphones (unmeaningful auditory distracter condition), (6) in the middle of two response-incompatible distracter pictures (either ties or shirts) with a response-incompatible article of clothing name (either tie or shirt) presented through headphones (meaningful visual plus auditory distracter condition), and (7) in the middle of two irrelevant distracter pictures (purses) with an irrelevant article of clothing name (purse) presented through headphones (unmeaningful visual plus auditory distracter condition). Stimuli durations and sizes are presented in Table 1 and example visual displays are presented in Figure 1.

Table 1 Stimuli Sizes and Presentation Duration.

VISUAL STIMULI	DURATION AND SIZE		AUDITORY STIMULI	DURATION
TIE (target / distracter)	3000 ms	1.25cm long .75cm wide	TIE	276.05 ms
SHIRT (target / distracter)	3000 ms	1.10cm long 1.25cm wide	SHIRT	361.00 ms
PURSE (distracter)	3000 ms	1.10cm long 1.10cm wide	PURSE	388.00 ms

Children sat in a chair that was positioned approximately 40 cm from the computer monitor. During the testing procedure participants wore TM-101 stereo headphones

Figure 1. The seven conditions within the visual selective attention task.



connected to the computer for presentation of auditory stimuli. Participants were presented with 24 trials (picture displays) per condition, totaling 168 trials. One of target articles of clothing (the shirt or the tie) appeared at the center of the monitor for each trial. All conditions were mixed within three blocks of 56 trials and presented in a random order.

The children were asked to respond to stimuli by pressing a certain key on a computer keyboard if the picture of one target article of clothing (the tie) was presented at the center of the computer monitor, and a different key if the other target article of clothing (the shirt) appeared in the center of the monitor. The keys used for the shirt and tie were counterbalanced across participants. The children's responses triggered the offset of each presented stimulus. The visual stimulus remained on the computer monitor for a maximum of 3000ms or until the child responded. Between the offset of one trial and the onset of the next trial the screen was blank for 1000ms. Accuracy (percent correct) and reaction time (speed in responding to the stimulus) were recorded.

Teachers were requested to complete the CTRS-28 (Conners, 1989) to ensure that children in the control group did not have attentional problems. The CTRS-28 is a paper and pencil rating instrument. It consists of 28 items that are rated with one of four responses (not at all, just a little, pretty much, or very much) by the teacher and then scored on a scale of 0 to 3. Children who received T-scores of less than 65 on all the subscales (Conduct Problems, Hyperactivity, Inattentive-Passive and Hyperactivity Index) of the CTRS-28 were included in the control group.

Procedure

The control children were recruited through the Kings County School Board, Nova Scotia. After receiving permission to conduct the study in the schools, the principal of an elementary school was requested to distribute parental permission forms (see Appendix A) to classrooms that consisted of children in the appropriate age groups. Interested parents completed and returned the forms. The teacher was requested to complete a CTRS-28 on each child that had parental permission to participate in the study.

The children with ADHD were recruited through a mental health clinic in Windsor, Nova Scotia and the Attention Deficit Association of Nova Scotia. After receiving permission to complete the study in the mental health clinic, the psychologist on staff was requested to distribute parental permission forms (see Appendix B) to the parents of children who had been diagnosed with ADHD and were under the age of 12. The psychologist distributed the forms by mailing information to the parents. The psychologist was provided with information packages ready for distribution to the parents. This procedure allowed for the confidentiality of the clients. Interested parents completed and returned the form. Following the return of the permission forms, parents were contacted concerning their child's participation in the study and the child's file was reviewed to determine how and when diagnostic criteria were determined and how long the child had been taking methylphenidate. Fifty percent of the permission forms were completed and returned.

After receiving permission to complete the study at the Attention Deficit

Association parental permission forms were mailed to members with the regular mail out of a newsletter. This procedure allowed for the confidentiality of the members. It could not be determined prior to the mailout who would meet the criteria so parental permission forms (see Appendix C) were mailed out to all members in Halifax, Dartmouth, Bedford, and Sackville, Nova Scotia. Interested parents completed and returned the form. Following the return of the permission forms, parents were contacted concerning their child's participation in the study and the child's therapist was contacted to determine how and when diagnostic criteria were determined and how long the child had been taking methylphenidate. Due to the mailout procedure it was not possible to determine the return rate of the individuals who met the criteria for the study.

Children were instructed of the procedure that needed to be followed in order to complete the visual selective attention task (see Appendix D) followed by a short practice session. The display consisted of the presentation of a fixation point (+) on the center of the screen followed by the picture display. The participants received feedback at fixation following each trial ("+" for correct, "-" for incorrect). This feedback then served as the fixation for the subsequent trial. The task was completed in a quiet room and the running time was approximately 15 minutes. Children in the ADHD group were tested under a no methylphenidate and methylphenidate condition. The order in which these conditions were tested was completely counterbalanced to control for ordering effects.

Following the completion of the task the children were thanked for their participation. General information concerning the results of the completed study was provided in written form to the parents following completion of the study.

Results

Descriptive Statistics

Children with ADHD and children without ADHD were tested in two age groups: 6- to 8-years-old and 9- to 11-years-old (refer to Table 2). The younger age group differed significantly in age from the older age group in both the ADHD group [$t(22)=25.74$, $p<.01$] and the control group [$t(30)=41.42$, $p<.01$]. The younger ADHD group and younger control group did not differ in age [$t(24)=0.25$, n.s.] nor did the older ADHD and older control group [$t(28)=1.83$, n.s.].

Table 2: Participant Descriptives

	Control (younger)	Control (older)	ADHD (younger)	ADHD (older)
# Males	11	15	10	10
# Females	3	3	2	2
Age (years-months)				
Range	6-7 to 8-3	9-5 to 11-2	6-7 to 8-6	9-0 to 11-11
Mean (SD)	7-5 (0-7)	10-7 (0-7)	7-5 (0-11)	10-5 (1-1)

The family SES was determined for each child, using the 1981 socioeconomic index for occupations in Canada (Blishen, Carroll, & Moore, 1987). The SES scores for

To ensure that children in the control group did not have attentional problems, teachers were requested to complete the CTRS-28 (Conners, 1989). Children who received T-scores of less than 65 on all the subscales of the CTRS-28 were included in the control group. Refer to Table 3 for the mean (SD) CTRS-28 scores of children in the younger and older control groups. The younger and older control groups did not differ significantly on the Conduct Problem subscale [$t(30) = 1.55$, n.s.], the Hyperactivity subscale [$t(30) = 0.14$, n.s.], the Inattentive/Passive subscale [$t(30) = 0.34$, n.s.], nor the Hyperactivity Index [$t(30) = 0.16$, n.s.].

Table 3: CTRS-28 Subscale Scores for Control Group

	Conduct Problem	Hyperactivity	Inattentive/ Passive	Hyperactivity Index
Younger				
Mean	47.79	46.71	44.07	45.07
SD	5.87	4.75	5.15	4.05
Older				
Mean	45.11	46.44	44.94	45.39
SD	3.97	6.13	8.33	6.53

Selective Attention Task

Data for correct reaction time (RT; in msec), accuracy (percent correct), and efficiency (reaction time divided by proportion correct) were analyzed separately using Mixed Design Analysis Of Variance. Follow up analysis were conducted using Tukey's HSD procedure. The variables "age" (younger or older) and "group" (ADHD or nonADHD) were between groups measures. The variables "MPH" (on or off), " distracter modality" (visual, auditory, or both), and "distracter meaning" (meaningful or unmeaningful) were repeated measures. For each dependent measure, separate analyses were conducted comparing the control group to the ADHD group on and off-MPH and comparing the ADHD group's performance on and off-MPH.

Unequal sample sizes in repeated measures designs may result in a violation of the assumption of sphericity. To account for potential violations, the Geisser-Greenhouse corrected probabilities were used to determine significance for all repeated measures effects.

Reaction Time

Control vs. ADHD (off-MPH).

The control group was compared to the ADHD (off-MPH) group using a 2 (group) x 2 (age) x 3 (distracter modality) x 2 (distracter meaning) ANOVA. Three main effects were significant (refer to Table 4 for means and standard deviations). The main effect of group was significant [F (1, 52) = 4.67, $p < 0.05$], indicating that children with ADHD exhibited longer RTs than children without ADHD. Second, the main effect of age was significant [F (1,52) = 54.27, $p < 0.01$]. The younger group had significantly longer RTs than the older group. Also, the main effect of distracter modality was significant [F (2, 104) = 4.48, $p < 0.05$]. Post-hoc comparisons indicated that visual distracters, as well as the combination of visual and auditory distracters produced longer RTs than auditory distracters alone (see Appendix E). There was no significant difference in RT between the visual distracter condition and the condition which combined visual and

Table 4 : Means and Standard Deviations for Significant Main Effects of Reaction Time

		Mean	SD
Control and ADHD (off-MPH)			
Group	Control	966.68	289.12
	ADHD (off-MPH)	1088.66	192.38
Age	Younger	1203.05	192.65
	Older	859.42	195.78
Modality	Visual Distracters	1027.01	277.17
	Auditory Distracters	997.29	243.75
	Visual + Auditory Distracters	1032.58	256.09
Control and ADHD (on-MPH)			
Age	Younger	1152.93	216.81
	Older	819.70	163.22
Modality	Visual Distracters	973.00	259.86
	Auditory Distracters	933.71	236.84
	Visual + Auditory Distracters	980.84	252.60
Meaning	Meaningful	970.84	258.17
	Unmeaningful	954.20	242.16
ADHD			
Age	Younger	1116.36	192.92
	Older	929.26	160.27
MPH	Off	1088.66	192.38
	On	956.96	186.50
Modality	Visual Distracters	1039.00	212.52
	Auditory Distracters	997.32	194.18
	Visual + Auditory Distracters	1032.11	193.23

auditory distracters.

There were three significant two-way interactions. The group by age interaction was significant [F (1, 52) = 8.98, $p < 0.01$] (refer to Figure 2). Group RTs were not significantly different for the younger age group. Children with ADHD (off-MPH), however, were significantly slower than control children in the older age group (see Appendix E). Both groups exhibited improvement with age.

The distracter modality by age interaction was also significant [F (2, 104) = 3.62, $p < 0.05$] (refer to Figure 3). This interaction indicates that the two age groups did not follow the same trend in reaction times when distracter modality was taken into consideration. Post-hoc comparisons showed younger children were slower to respond to targets when they were presented with visual or visual + auditory distracters than when they were presented with auditory distracters. The older children, however, show similar and shorter RTs across all three distracter modalities (see Appendix E). This suggests that children in the younger group were more affected by the nature of the distracter than children in the older group.

The third significant interaction was distracter meaning by group [F (1, 52) = 4.53, $p < 0.05$] (Refer to Figure 4). The children with ADHD (off-MPH) did not show a significant difference in RT between meaningful and unmeaningful distracter conditions whereas the children without ADHD were significantly faster with the presentation of unmeaningful distracters compared to meaningful distracters (see Appendix E for results of Tukey HSD). All other interactions failed to reach significance.

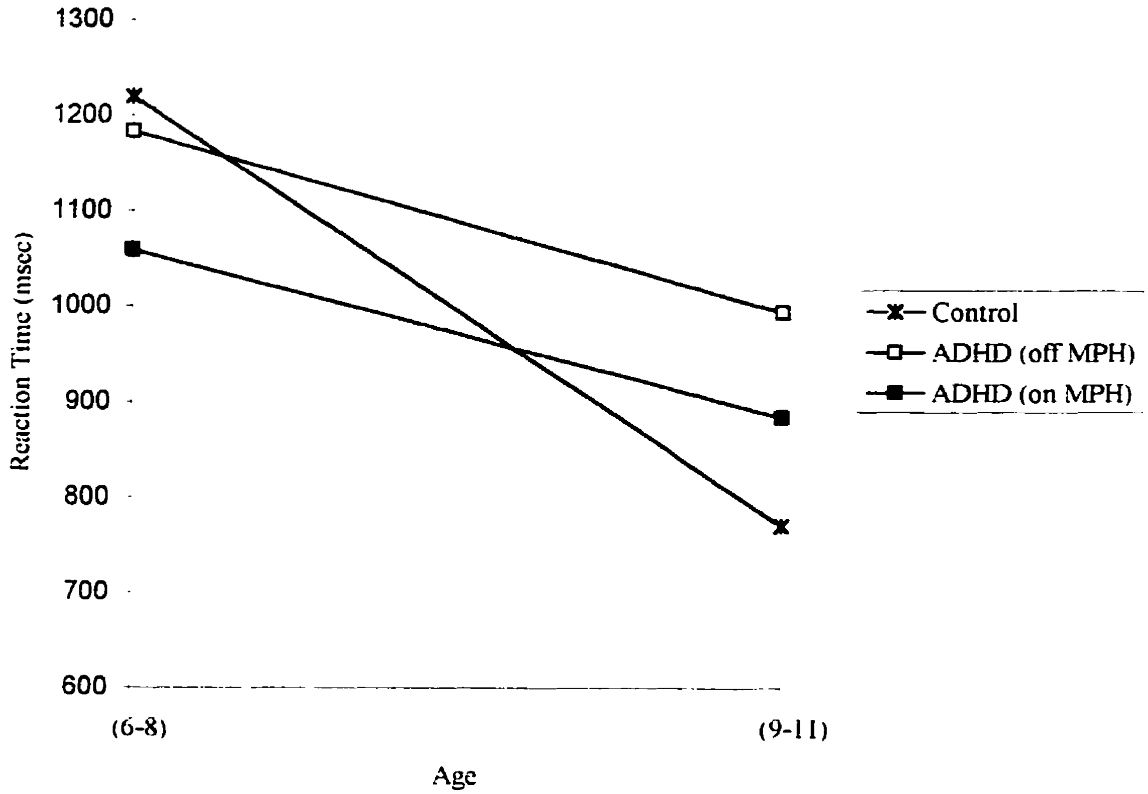


Figure 2: Mean RT (msec) as a Function of Group and Age.

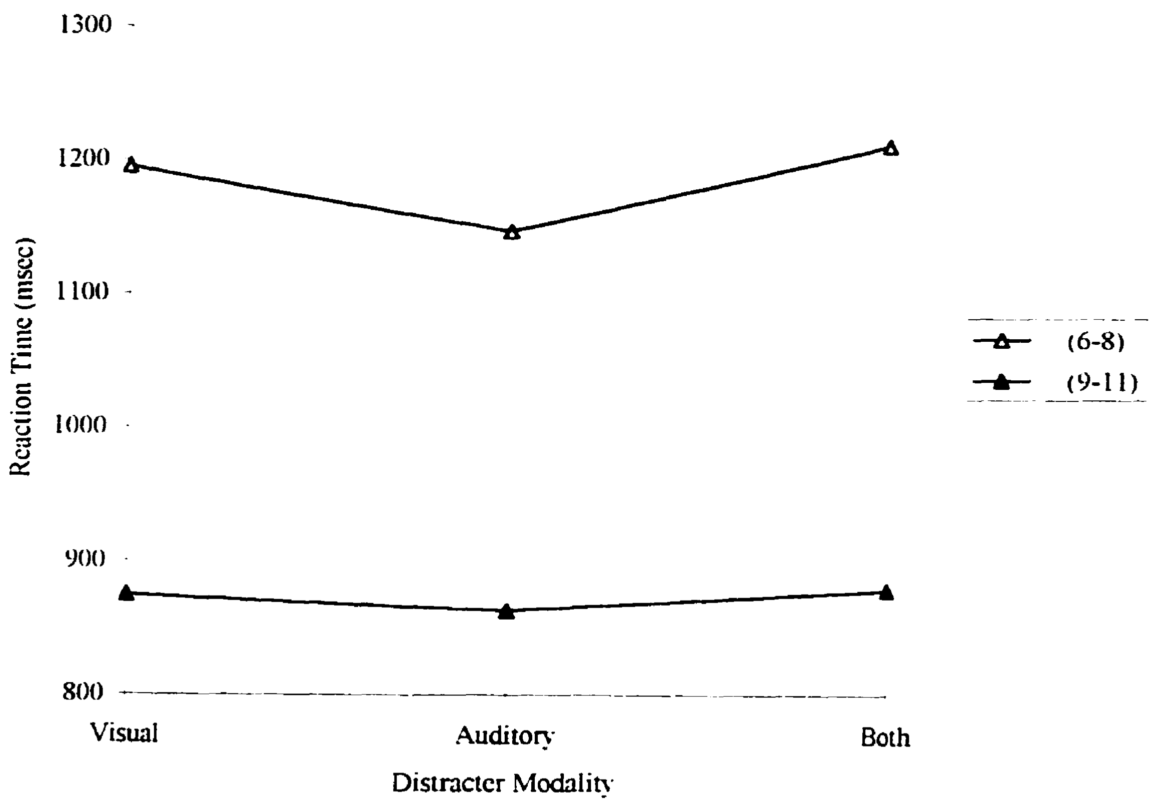


Figure 3: Mean RT (msec) as a Function of Age and Distracter Modality for the Control and the ADHD (off Methylphenidate) Groups.

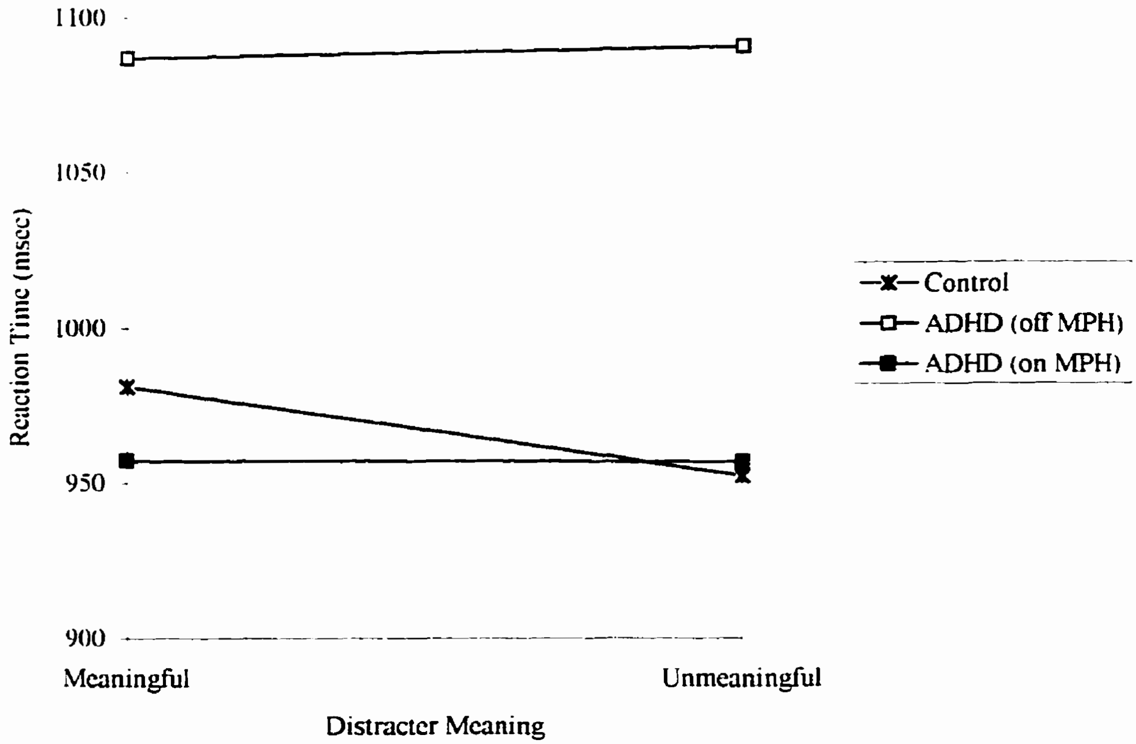


Figure 4: Mean RT (msec) as a Function of Group and Distracter Meaning.

Control vs. ADHD (on-MPH).

The control group was compared to the ADHD (on-MPH) group using the same analyses as the ADHD (off-MPH) comparison. Three main effects were significant (refer to Table 4 for means and standard deviations). First, the main effect of age was significant [F (1, 52) = 49.54, $p < 0.01$]. Second, the main effect of distracter modality was significant [F (2, 104) = 8.73, $p < 0.01$]. Post-hoc comparisons indicated that visual distracters, as well as the combination of visual and auditory distracters had longer RTs than auditory distracters alone (see Appendix E). There was no significant difference between the visual distracter condition and the condition which combined visual and auditory distracters. Also, a main effect of distracter meaning was significant [F (1, 52) = 5.30, $p < 0.05$], indicating that meaningful distracters resulted in longer RTs than unmeaningful distracters. There was no main effect of group.

Two two-way interactions were significant. First, the significant interaction of group by age [F (1,52) = 9.54, $p < 0.01$] indicated that younger children with ADHD (on-MPH) showed faster RTs than control children of the same age whereas older children with ADHD (on-MPH) showed similar RTs to control children of the same age (refer to Figure 2 and Appendix E). The distracter meaning by group interaction was also significant [F (1, 52) = 4.23, $p < 0.05$] (refer to Figure 4). The control group had slower RTs in the meaningful condition than in the unmeaningful condition whereas the two conditions did not differ for the ADHD (on-MPH) group (see Appendix E).

ADHD (off-MPH vs. on-MPH).

The RTs of children with ADHD (on and off-MPH) were compared using a 2 (MPH) x 2 (age) x 3 (distracter modality) x 2 (distracter meaning) mixed ANOVA. Three main effects were significant (refer to Table 4 for means and standard deviations). The first was the main effect of age [F (1,22) = 14.73, $p < 0.01$; younger RT > older RT]. Second, there was a main effect of MPH [F (1, 22) = 14.52, $p < 0.01$]. Children with ADHD had longer reaction times when they were off-MPH than when they were on-MPH. Also, there was a main effect of distracter modality [F (2, 44) = 5.04, $p < 0.05$]. Post-hoc comparisons indicated that visual distracters, as well as the combination of visual and auditory distracters had longer RTs than auditory distracters alone (see Appendix E). There was no significant difference in RT between the visual distracter condition and the condition which combined visual and auditory distracters. No interactions were significant.

Distracter Effects.

To obtain measures of overall interference caused by distracters, distracter difference scores were calculated by subtracting the RTs for meaningful and unmeaningful distracter modality conditions from the RTs of the no-distracter condition. One sample t-tests were then completed on the distracter difference scores to determine if the difference scores were significantly different from zero. Distracter difference scores that are significantly greater than zero indicated significant interference caused by a specific distracter relative to the no-distracter condition. The distracter difference scores indicated that RTs were longer when the target item was presented with visual distracters (meaningful and unmeaningful), auditory distracters (meaningful and unmeaningful), and visual + auditory distracters (meaningful and unmeaningful) than when the target was presented without distracters. This was true for the younger and older control groups and the younger and older ADHD (on and off-MPH) groups. Thus, distracters created interference relative to no-distracter conditions for children in the Control, the ADHD (off-MPH), and the ADHD (on-MPH) conditions.

The distracter difference scores were compared to determine if distracters cause more interference for children with ADHD (off-MPH) than for children with ADHD (on-MPH) or the children without ADHD. The analyses completed for the RT distracter difference scores were identical to the analysis of the RT distracter scores. Follow up analyses were conducted using Tukey's HSD procedure (see Appendix G).

Results of the analysis comparing children with ADHD (off-MPH) and children without ADHD revealed that children with ADHD (off-MPH) were more distracted by the presence of all distracter conditions (modality and meaning) than children without ADHD [F (1,52) = 9.13, p <0.01]. The distracter modality main effect [F (2,52) = 4.81, p <0.05] indicated that children were more distracted by visual distracters and a combination of visual and auditory distracters than auditory distracters alone. Two interactions were significant. First, the distracter modality by age interaction [F (2,104) = 3.62, p <0.05] indicated different patterns of responding for the two age groups. The older group showed similar difference scores across all modalities whereas the younger group was more distracted by visual distracters and a combination of visual and auditory distracters than auditory distracters alone. The second significant interaction was distracter meaning by group [F (1,52) = 4.53, p <0.05]. Children with ADHD (off-MPH) in the younger and older age group responded similarly to meaningful and unmeaningful distracters whereas children without ADHD were more distracted by meaningful distracters than unmeaningful distracters.

Children with ADHD (on-MPH) did not differ significantly from the children without ADHD. The analysis comparing these two groups found a main effect of distracter modality [F (2,104) = 9.22, p <0.01]. Visual distracters and a combination of visual and auditory distracters caused more interference in responding than auditory distracters alone. The main effect of distracter meaning [F (1,52) = 5.41, p < 0.05] indicated that meaningful distracters caused more interference than unmeaningful distracters in this analysis. Two significant interactions were significant. First, the meaning by group interaction was significant [F (1,52) = 5.12, p < 0.05]. Children with ADHD (on-MPH) were similarly distracted by both meaningful and unmeaningful distracters while children without ADHD were more distracted by meaningful than unmeaningful distracters. The second significant interaction was distracter meaning by age [F (2,52) = 5.72, p < 0.05]. This interaction revealed that while older children were distracted similarly by both meaningful and unmeaningful distracters, younger children were more distracted by meaningful than unmeaningful distracters.

The analysis comparing children with ADHD on-MPH and off-MPH indicated that children with ADHD were more distracted by all distracter conditions (modality and meaning) when they were off-MPH than when they were on-MPH [F (1,22) = 4.80, p <0.05]. The main effect of distracter modality [F (1,22) = 5.04, p <0.01] indicated that children were more distracted by the presence of visual distracters and the combination of visual and auditory distracters than the auditory distracters alone. No interactions were significant.

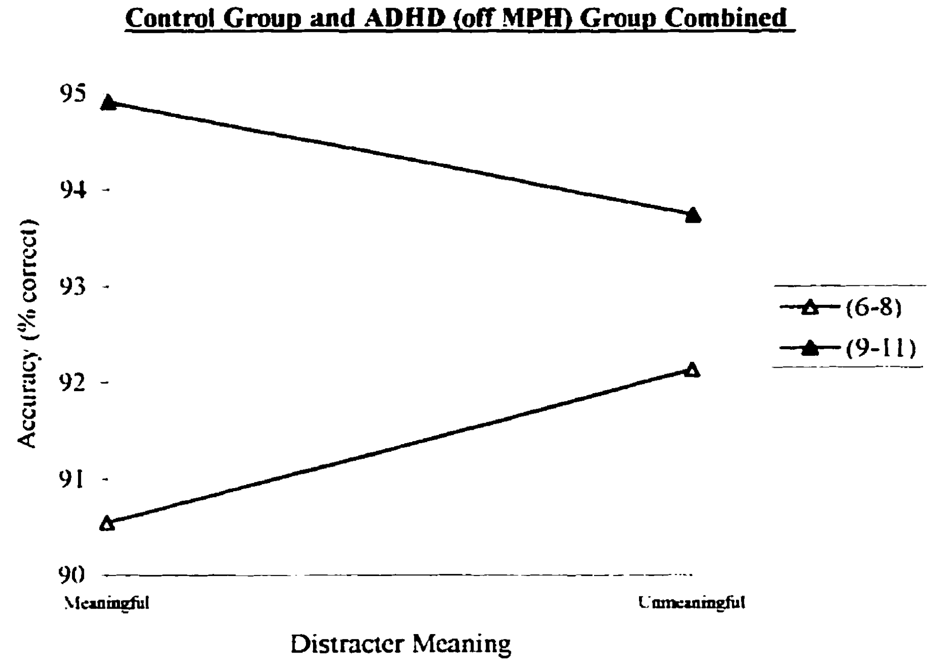
Thus, RT distracter difference scores indicated that distracter conditions caused more interference than the no-distracter condition. In addition, the distracters caused more interference for children with ADHD (off-MPH) than children with ADHD (on-MPH) or children without ADHD. Other significant main effects and interactions resulted in similar findings as the RT data previously discussed.

Accuracy

The analyses completed for the accuracy scores were identical to the analyses completed for the RT scores.

Control vs. ADHD (off-MPH).

One main effect was found to be significant in the accuracy data. The group main effect was significant [F (1, 52) = 24.62, p < 0.01] with the Control group (M = 96.15, SD = 4.80) responding to the task with greater accuracy than the ADHD group (M= 88.65, SD = 10.15). One two-way interaction was significant. The significant distracter meaning by age interaction [F (1, 52) = 4.80, p < 0.05] (see Figure 5) indicated that younger children responded less accurately than older children with the presentation of meaningful distracters while both age groups responded with similar accuracy to the



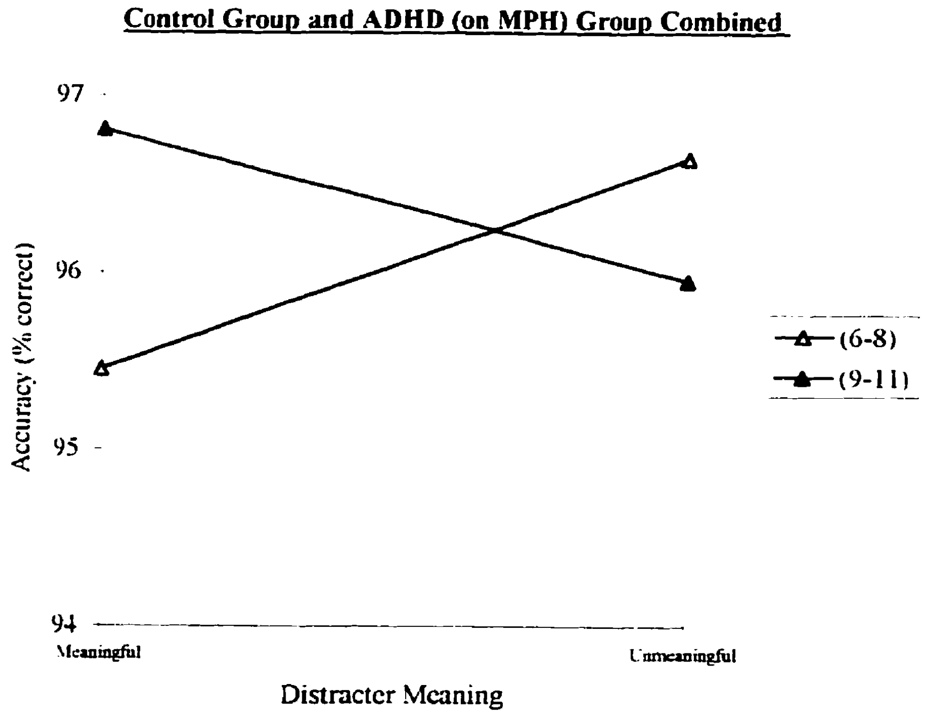


Figure 5: Mean Accuracy (% correct) as a Function of Distracter Meaning and Age.

presentation of unmeaningful distracters (see Appendix E).

One three-way interaction was significant. The distracter modality by group by age interaction was significant [F (2, 104) = 3.39, $p < .05$] (refer to Figure 6). Observation of Figure 6 and results of the Tukey HSD post-hoc comparison (see Appendix E) indicate that accuracy did not vary with age at any modality for the control group. For the ADHD (off-MPH) group, however, age differences in accuracy were noted, the largest being in the auditory distracter condition. The lack of differences in the control group may be due to ceiling effects. The younger ADHD (off-MPH) group, which had the lowest accuracy scores of the groups, showed higher accuracy in responding when presented with a combination of visual and auditory distracters compared to auditory distracters alone but did not show any significant difference in accuracy between visual and auditory distracter conditions or visual and a combination of visual and auditory distracter conditions.

Control vs. ADHD (on-MPH).

The two-way interaction of Meaning by Age was significant [F (1, 52) = 3.85, $p < 0.05$]. Again this interaction (refer to Figure 5), indicates that younger children respond more accurately when presented with unmeaningful distracters than meaningful distracters and that older children respond more accurately when presented with meaningful distracters than unmeaningful distracters. This trend was not significant with post-hoc comparisons (see Appendix E).

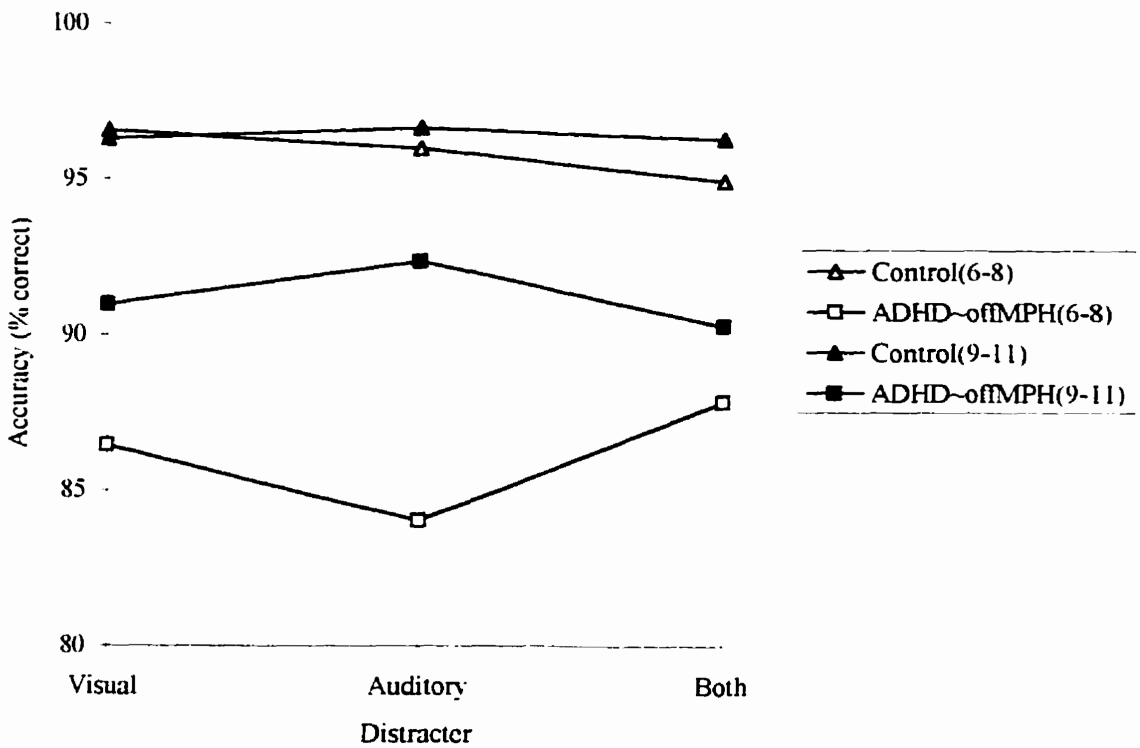


Figure 6: Mean Accuracy (% correct) as a Function of Group, Age, and Distracter Modality for Control and ADHD (off Methylphenidate).

ADHD (off-MPH vs. on-MPH).

The main effect of MPH was significant [F (1,22) = 30.63, $p < 0.01$] for the accuracy data. Children with ADHD had a significantly higher percentage of correct responses when they were on-MPH (M = 96.38, SD = 5.17) than when they were off-MPH (M = 88.65, SD = 10.15).

Two two-way interactions were found to be significant. The MPH by age interaction was significant [F (1,22) = 5.88, $p < 0.05$] (refer to Figure 7). This interaction suggests that although both age groups of children with ADHD show higher accuracy when on-MPH than when off-MPH , children in the younger age group show a much larger increase in accuracy than children in the older age group. When the children are off-MPH, younger children show lower accuracy than older children but when they are on-MPH there is no significant difference between the two age groups (see Appendix E).

The distracter modality by age interaction was significant [F (2,44) = 3.88, $p < .05$] (refer to Figure 8). Although not significant with post-hoc testing, younger children showed the following pattern of accuracy for presentation of distracter modalities from highest accuracy to lowest : Visual + Auditory Distracters > Visual Distracters > Auditory Distracters whereas for older children the pattern of accuracy for presentation of distracter modalities from highest accuracy to lowest was as follows: Auditory Distracters > Visual Distracters > Visual + Auditory Distracters.

Distracter Effects.

Distracter difference scores were calculated by subtracting the accuracy scores for

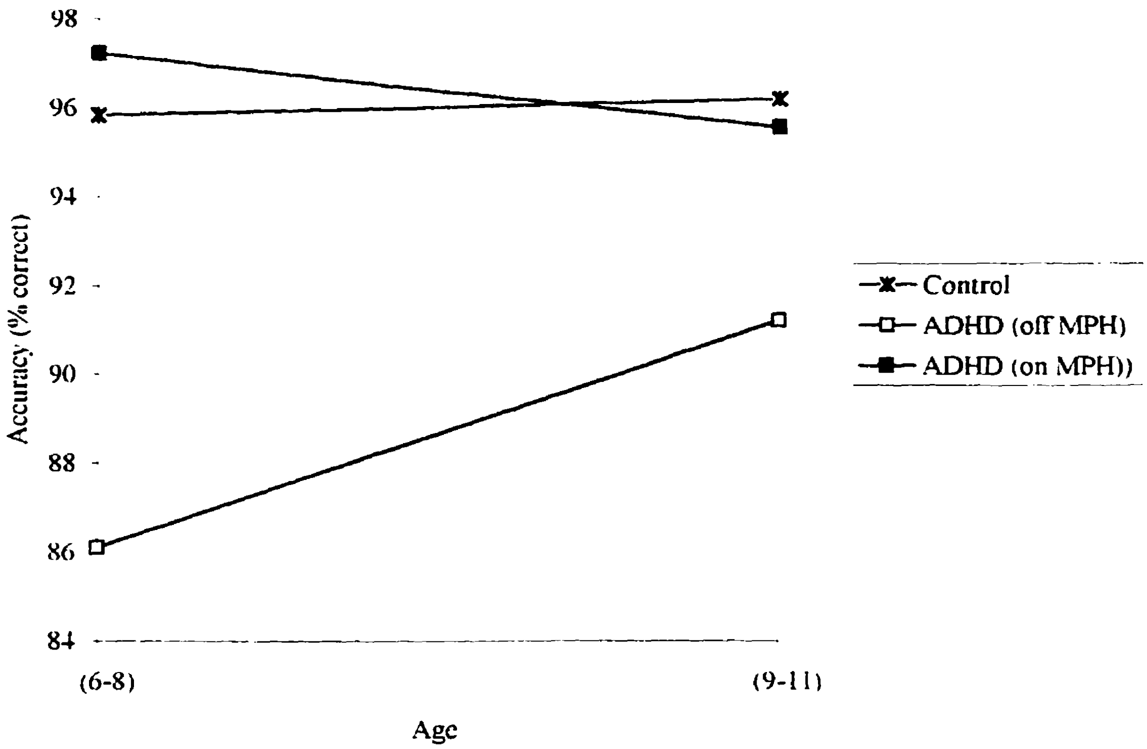


Figure 7: Mean Accuracy (% correct) as a Function of Age and Group.

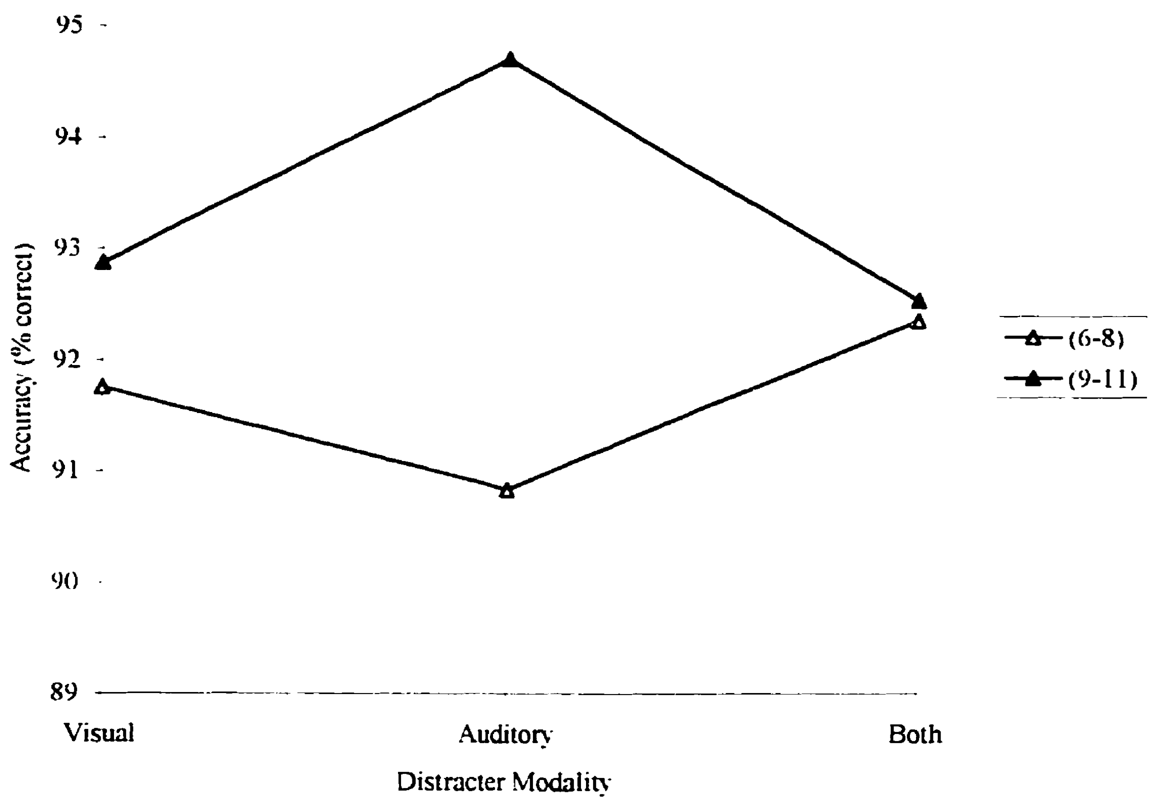


Figure 8: Mean Accuracy (% correct) as a Function of Modality and Age for the ADHD Group (on and off MPH combined).

the no-distracter condition from the accuracy scores of the meaningful and unmeaningful distracter modality conditions. One sample t-tests were then completed on the distracter difference scores to determine if the difference scores were significantly different from zero. If the distracter difference score is significantly greater than zero then the distracter condition is causing a decrease in accuracy as compared to the no-distracter condition. Most of the distracter difference scores indicate that accuracy scores were similar whether the target item was presented with distracters [visual (meaningful or unmeaningful), auditory (meaningful or unmeaningful), or both (meaningful or unmeaningful)] or without distracters for children in the Control, ADHD (off-MPH), and ADHD (on-MPH) conditions (see Appendix F). The only significant difference in accuracy between distracter and no-distracter conditions was found when the older control group was presented with visual, unmeaningful distracters [$t(17) = 2.50$, $p < .05$].

Efficiency

In this study not all groups showed similar levels of accurate responding. When accuracy scores differ between groups the possibility that different strategies are being used needs to be considered. For example, a low accuracy score and high reaction time score may suggest that the child is responding impulsively. Efficiency scores are used to incorporate RT scores and accuracy scores into one score by dividing RT by proportion correct (Townsend & Ashby, 1983). This one score can then reflect any trade off a child may be making between accuracy and RT. A low efficiency score represents high efficiency in responding (i.e., low RT, high accuracy) whereas a high efficiency score represents low efficiency in responding (i.e., high RT, low accuracy). The analyses completed on Efficiency scores were identical to analyses on RT and accuracy scores.

Control vs. ADHD (off-MPH).

Two main effects were significant (refer to Table 5 for means and standard deviations). The main effect of group was significant [F (1, 52) = 14.95, $p < .01$]. The Control group was more efficient in responding to the stimuli than the ADHD-off-MPH. Second, the main effect of age was significant [F (1, 52) = 49.68, $p < .01$]. Children in the older age group responded more efficiently to the task than children in the younger age group.

The two-way, distracter meaning by age interaction was significant [F (1, 52) = 5.38, $p < .05$] (see Figure 9). Children in the older age group maintained relatively similar efficiency scores for meaningful and unmeaningful distracters whereas the younger age group were more efficient at responding when the distracter was meaningful than when it was unmeaningful (see Appendix E).

Control vs. ADHD (on-MPH).

There were three significant main effects (refer to Table 5 for means and standard deviations). First, the main effect of age was significant [F (1, 52) = 44.95, $p < 0.01$]. The children in the older age group responded more efficiently than the children in the younger age group. The main effect of distracter modality was also significant [F (2, 104) = 9.57, $p < 0.01$]. Post-hoc comparisons indicated that responses were less efficient when targets were presented with visual distracters, or a combination of visual and auditory

Table 5: Means and Standard Deviations for Significant Main Effects of Efficiency

		Mean	SD
Control and ADHD (off-MPH)			
Group			
	Control	1010.17	315.14
	ADHD (off-MPH)	1251.48	297.29
Age			
	Younger	1333.88	270.67
	Older	922.66	246.90
Control and ADHD (on-MPH)			
Age			
	Younger	1186.23	238.10
	Older	845.27	185.67
Modality			
	Visual Distracters	1014.91	282.46
	Auditory Distracters	966.81	251.55
	Visual + Auditory Distracters	1029.00	277.63
Meaning			
	Meaningful	1014.50	288.49
	Unmeaningful	992.65	253.54
ADHD			
Age			
	Younger	1239.44	297.05
	Older	1006.83	214.10
MPH			
	Off	1251.48	297.29
	On	994.79	199.40

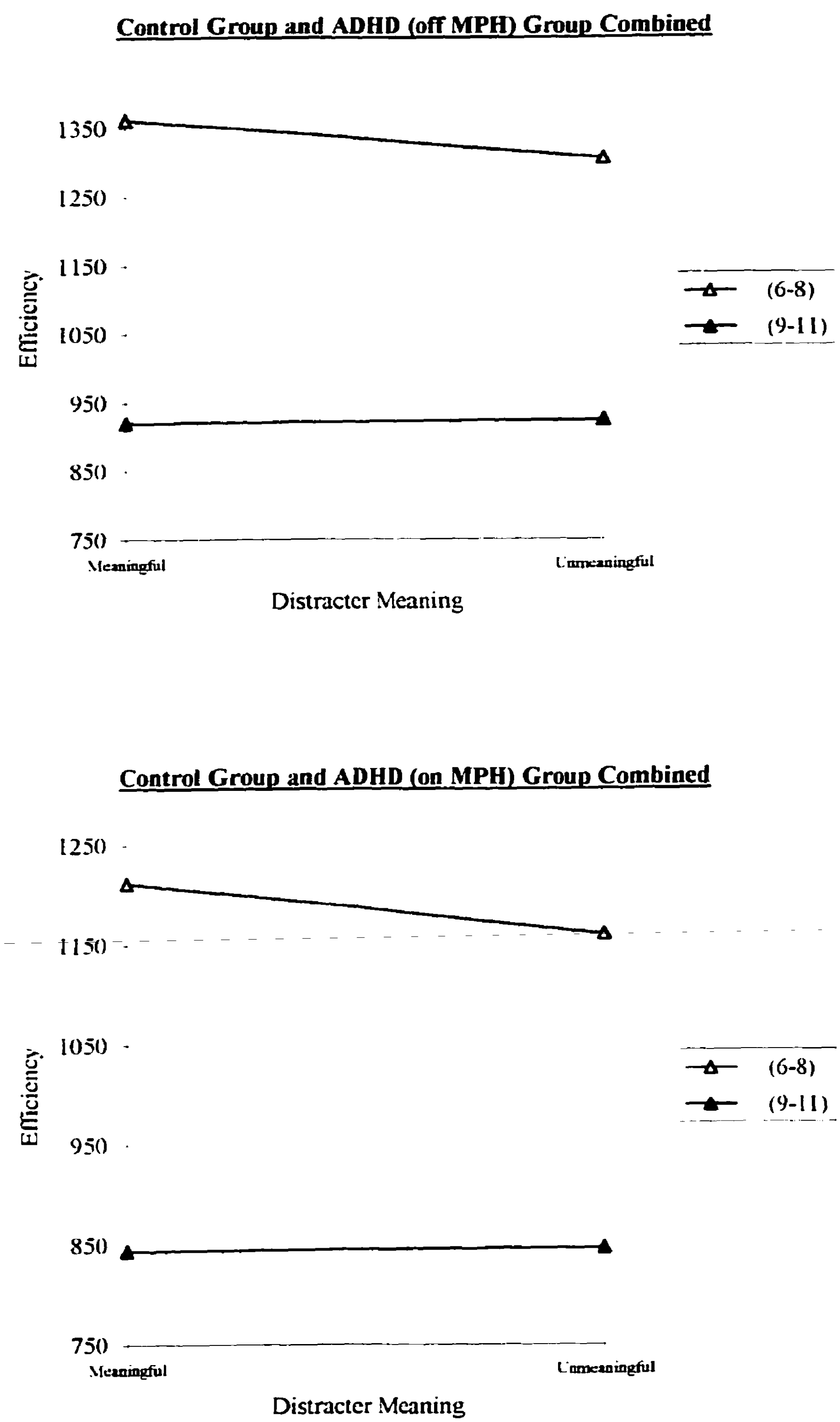


Figure 9: Mean Efficiency as a Function of Distracter Meaning and Age.

distracters than when targets were presented with auditory distracters alone (see Appendix E). There was no significant difference in efficiency between the visual distracter condition and the condition which combined visual and auditory distracters.

Three two-way interactions were significant. The group by age interaction was significant [$F(1, 52) = 10.13$, $p < 0.01$] (refer to Figure 10). In the younger age group children with ADHD (on-MPH) were more efficient in their responding than the control children but in the older age group children in the control group and the ADHD (on-MPH) group responded with similar efficiency (see Appendix E). There was also a significant distracter meaning by group interaction [$F(1, 52) = 4.26$, $p < 0.05$] (refer to Figure 11). This interaction showed that the ADHD (on-MPH) group responded similarly with the presentation of meaningful and unmeaningful distracters but that the control group responded more efficiently to the presentation of unmeaningful than meaningful distracters (see Appendix E). The third significant interaction was distracter meaning by age [$F(1, 52) = 13.84$, $p < 0.01$] (refer to Figure 9). This interaction indicates that older children maintained a similar level of efficiency across meaningful and unmeaningful distracters, whereas younger children are more efficient at responding when they are presented with unmeaningful distracters than meaningful distracters (see Appendix E). This interaction suggests a larger age difference in efficiency for meaningful distracters than for unmeaningful distracters.

ADHD (off-MPH vs. on-MPH).

There were two main effects of efficiency in the analysis of children with ADHD

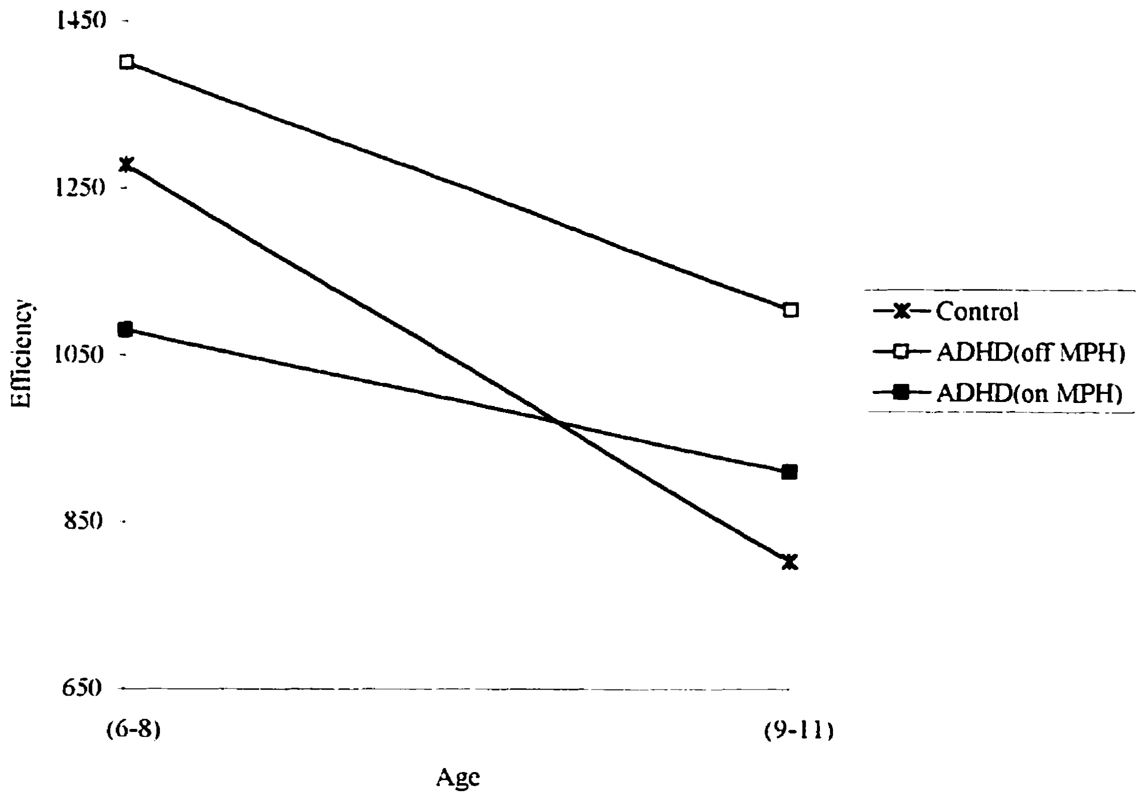


Figure 10: Mean Efficiency as a Function of Group and Age.

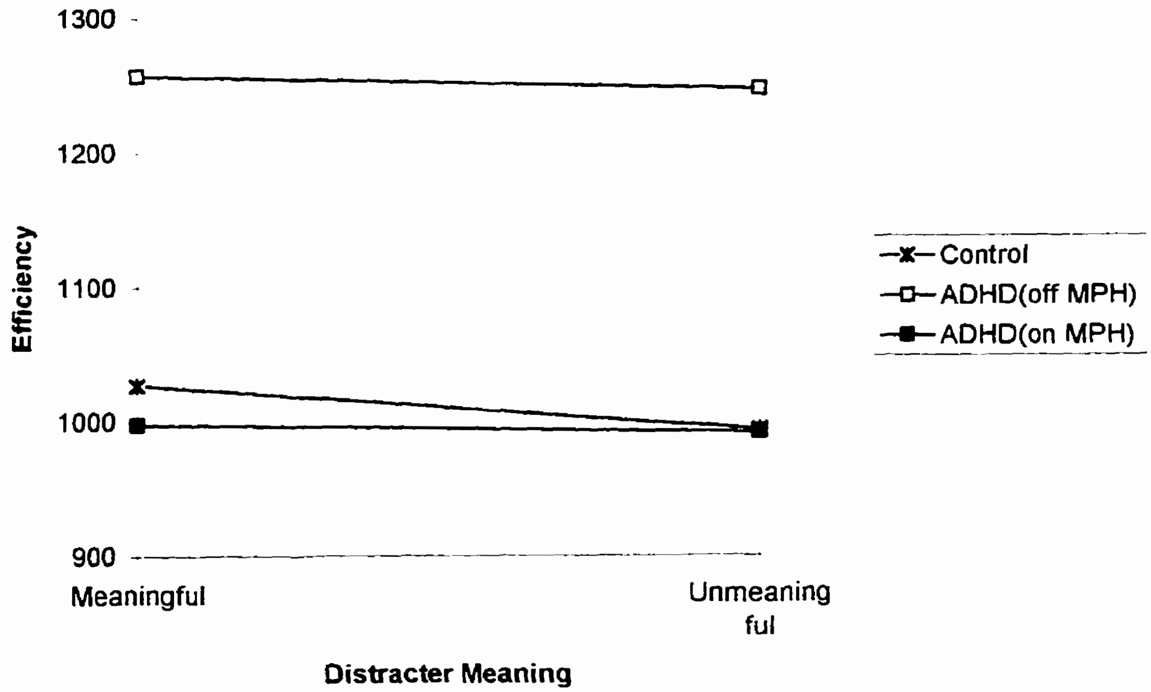


Figure 11: Mean Efficiency as a Function of Group and Distracter Meaning.

(refer to Table 5 for means and standard deviations). First, there was a main effect of age [F (1,22) = 12.35, $p < .01$] suggesting that older children responded more efficiently than younger children. Second, there is a main effect of MPH [F (1,22) = 40.00, $p < 0.01$] illustrating that children on-MPH responded more efficiently than children off-MPH. All other effects failed to reach significance.

Socio-Economic Status (SES) and Selective Attention

Analysis of Covariance (ANCOVA) was completed on all the preceding efficiency analysis using SES as a covariate. Although there was no significant effect of SES for the analysis there were some changes to significant effects when SES was a covariate. In this section all effects that have changed are reported.

No main effects or interactions were lost from the Control and ADHD (off-MPH) analyses as a result of using SES as a covariate. The addition of SES as a covariate to the analysis with the Control and the ADHD (on-MPH) changed the main effects of distracter modality and distracter meaning from significant to not significant. No main effects or interactions were lost when SES was added to the analysis of the ADHD group when they were on and off-MPH.

Discussion

The results indicate that children with ADHD are more distractible than children without ADHD of the same age. When children with ADHD are on-MPH, however, their performance on selective attention tasks improves significantly. Consistent across all conditions was the fact that children with ADHD were more impaired in their performance than children without ADHD and that older children performed more efficiently than younger children in both the ADHD and control groups.

Selective Attention and ADHD

All groups exhibited interference effects with measures of RT and efficiency. This section will discuss the nature of these interference effects for the different groups in this study.

It was hypothesized that children with ADHD should find it more difficult to ignore irrelevant information while trying to process and respond to target information. In the present study, children with ADHD were less efficient than children without ADHD in the same age group. Moreover, the performance of the ADHD group was less efficient than the control group for all distracter types. Furthermore, children with ADHD did not perform as efficiently as the children without ADHD even in trials that did not contain any distracters. Thus, results are consistent with Ceci and Tishman (1984) and Pearson et al. (1995) who found that children with ADHD did not perform as efficiently as children without ADHD on attention tasks.

Ceci and Tishman (1984) claimed that when learning conditions are made demanding (e.g., time restricted, numerous distracters), the performance of children with ADHD will decrease in efficiency to an extent greater than their same age peers. According to Ceci and Tishman (1984) demanding learning conditions require the total use of limited capacity attentional resources. Children with ADHD may have a more limited capacity, resulting in processing deficits.

Studies on Auditory Evoked Response Potential (AERP) waves (e.g. Klorman, 1991; Satterfield et al., 1990) suggest that P3b waves may be associated with deficits in selective attention. Results of the study by Satterfield et al. (1990) indicated that the deficit in selective attention may have been a result of insufficient processing of the relevant stimuli. In other words, children with ADHD focused their attention on irrelevant information, limiting the available resources for processing of the target. If children with ADHD are having more difficulty with processing and encoding stimuli they may not be able to prepare sufficiently for upcoming stimuli. This may result in an attention deficit on all trial types not just for the items with distracters present. The results of the present study are consistent with an argument that processing deficits are present overall rather than just in the presence of distracters.

This is consistent with the findings of Higginbotham and Bartling (1993) that children with ADHD do not show more or less interference depending on the modality of the distracters but were more distracted than children without ADHD even in the absence of a distracter. Higginbotham and Bartling (1993) suggested that not only do distracters affect the performance of a child with ADHD when the distracters are present but the distracters may also be impairing the child's ability to attend following distraction. Processing begins with the presentation of the first item which includes the target stimuli and possibly visual and/or auditory distracters. Retroactive interference (second item interferes with the first item) and proactive interference (first item interferes with the second) may occur from item to item (Higginbotham & Bartling, 1993). In the present study, the distracter and no-distracter conditions were combined in the task for each child. Thus, the distracters may have caused an overall interference effect similar to that reported by Higginbotham and Bartling (1993).

Clearly, more than the presence of distracters reduces the performance of children with ADHD. Even on a simple timed computer task, children with ADHD may be more influenced than controls by a number of factors related to attention (e.g., boredom, visual processing deficits). Boredom may influence the performance of a child with ADHD significantly more than a child without ADHD. A child with ADHD can not sustain attention for as long as a child without ADHD (e.g., Corkum & Seigal, 1993) and thus, may be become distracted from the task more so than controls. In the present study, however, the task was purposely designed to be completed in a short period of time to reduce the impact of boredom.

Visual processing deficits may also influence the ability of a child with ADHD to perform a visual computer task. Using a covert orienting computer task, Carter Krener, Chaderjian, Northcutt, and Wolfe (1995b) measured the ability of children with ADHD to process and respond to targets when presented with valid and invalid cues. Results indicated that children with ADHD have visual processing deficits that may be related to "a disruption of controlled attentional mechanisms in the right cerebral hemisphere" (p.797). Carter et al. (1995b) suggested that such processing deficits may influence a child's ability to sustain attention and cause difficulty inhibiting processing.

Questions were also raised concerning the influence of the modality of the distracters and the meaningfulness of the distracters. It was hypothesized that both the ADHD group and the control group would be more distracted from the task when both the visual and auditory distracters were presented together. Also, it was expected that children with ADHD would be more easily distracted than children without ADHD for all distracters. The smallest gap between the two groups was expected to be with the presentation of auditory distracters since auditory distractibility is reportedly associated with cognitive functioning (Bedi et al., 1994) and all children tested were functioning at their grade appropriate level. Visual distractibility, on the other hand, has been linked with hyperactivity and inattention (Bedi et al., 1994) and thus, conditions with visual distracters were expected to be more difficult for children with ADHD than children without ADHD.

The results of the present study indicated that the control group and the ADHD (on-MPH) group experienced the least interference from auditory distracters. Both visual distracters and the combination of visual and auditory distracters caused more interference for these two groups. This was expected given the task was visual and visual distracters provide modality-specific distraction. The ADHD (off-MPH) group, however, experienced similar task interference with visual distracters, auditory distracters and a combination of visual and auditory distracters. Although these results are not consistent with the findings of Bedi et al. (1994), it is possible that the interference caused by visual distracters in the present experiment may carry over and cause high overall levels of interference for children with ADHD (Higginbotham & Bartling, 1993). This argument is similar to the explanation for poorer performance by children with ADHD on no-distracter trials. Auditory and visual distractibility were measured in separate tasks by Bedi et al. (1994), thereby eliminating the potential for carry over interference effects in their study.

Distracters were further divided into meaningful and unmeaningful conditions. It was hypothesized that meaningful distracters would create more interference than unmeaningful distracters because meaningful distracters require inhibiting a response-incompatible to the target, whereas the unmeaningful distracters are irrelevant to the target. This difference was expected to be larger for younger children and for children with ADHD because both have been reported to experience difficulties inhibiting responses (e.g., Enns & Akhtar, 1989; Malone & Swanson, 1993). Children with ADHD (off-MPH and on-MPH) did not show a significant difference in reaction time between meaningful and unmeaningful distracters whereas children without ADHD were significantly faster with the presentation of unmeaningful distracters compared to meaningful distracters. This finding suggests that children with ADHD did not make a strong association between the target and response and therefore, were not differentially affected by the presence of distracters that required inhibiting a response, and those that did not. This association, that is seen in children without ADHD, is not evident even when children with ADHD are on-MPH. This finding may also be explained by the argument that children with ADHD do not distinguish between the varying distracter types within a single task. Rather, the fact that distracters are present at any point during the task makes the entire task more difficult for children with ADHD than children without

ADHD. It should be noted, however, that this effect was not modified by MPH treatment whereas the modality effect was.

Developmental Trends of Selective Attention

To understand the impact of childhood ADHD on selective attention this study addressed the issue of how selective attention abilities develop in children without ADHD and then compared this development to the development of selective attention in children with ADHD. It is a normal response for children of all ages, as well as adults, to need to take time to ignore distracters. This study hypothesized that older children would be more efficient than younger children at the selective attention task. In agreement with previous studies (e.g. Enns & Akhtar, 1989; DeMarie-Dreblow & Miller, 1988) the present study found that distracters caused less interference for children in the older age group than for children in the younger age group. As previously discussed, Enns and Akhtar (1989) suggested two potential reasons for an increase in efficiency in selective attention abilities as a child gets older. First, young children may have a limited capacity of attention that capacity increases as they get older. Second, young children may have deficits in skills that are needed to develop and use strategies for selective attention tasks. It is likely that as children get older their capacity for attention increases and they also develop more sophisticated strategies. These explanations are consistent with the age improvements noted in the present study.

It was also hypothesized that developmental trends would be similar for children with ADHD (off-MPH) and for children without ADHD. Data generally supported the hypothesis that older children would be more efficient than younger children whether the child had ADHD or not (see Figure 2). There is, however, a smaller difference with age for the ADHD (off-MPH) group than for the control group in both the Efficiency and RT data. Malone and Swanson (1993) have reported that the problems children with ADHD have with inhibitory control and impulsiveness persist into adolescence and adulthood. In the present study, children with ADHD never reached the level of performance that children in the control group reached, suggesting selective attention deficits persist as well. Children with ADHD (off-MPH) in the younger age group exhibited similar levels of performance to their same age peers without ADHD but the older children with ADHD (off-MPH) exhibited significantly poorer performance than their same age peers, suggesting that children with ADHD do not develop at the same rate as children without ADHD.

Accuracy did not vary from the younger to the older group for the control children. This is most likely due to the fact that a ceiling effect was found in both age groups. The children in the ADHD (off-MPH) group, however, showed age differences for accuracy results. Children with ADHD (off-MPH) in both the younger and older age groups were less accurate than control children in either age group. This finding suggests that although children with ADHD (off-MPH) increase their accuracy with age they are unable to develop skills to the level demonstrated by children without ADHD even if the children without ADHD are younger. This result and the reaction time data are consistent with the notion of a developmental lag in children with ADHD.

Although children with ADHD were not as efficient at the selective attention task as children without ADHD both groups showed an increase in efficiency with age. Pearson et al. (1995) suggested that children with ADHD may be developmentally immature in their ability to orient attention. Furthermore, since orienting may be a component of selective attention, children with ADHD would be expected to show some developmental immaturity in selective attention as well.

The impact of meaningful and unmeaningful distracters was also mediated by age. Children in the older age group demonstrated similar efficiency with meaningful and unmeaningful distracters whereas younger children were more efficient when the distracters were unmeaningful. Younger children were also less accurate than older children when the distracters presented were meaningful but were similar when the distracters were unmeaningful. In addition, younger children responded with higher accuracy to unmeaningful distracters than meaningful whereas older children respond with higher accuracy to meaningful distracters than unmeaningful distracters for both children with and without ADHD. Inhibitory control in younger children is reportedly not as well developed as in older children (Enns & Akhtar, 1989). Younger children therefore, may be more impulsive, and may be more likely to respond to distracters rather than the target. The same would be expected of children with ADHD in both age groups, although perhaps not when a child is treated with MPH (see below). In the present study, younger children were affected more by the nature of the distracters than older children.

Interestingly, children with ADHD (off-MPH) seem to be effected similarly by meaningful and unmeaningful distracters.

The results of the present study suggested that when studying children with ADHD, age groups should not be collapsed. When large age ranges are combined there is a potential to diminish or exaggerate deficits associated with the disorder. In order to truly understand ADHD and its implications for individuals, it is necessary to understand how the disorder changes with age throughout the lifespan.

The Effects of Methylphenidate on Attention

It was hypothesized that MPH would improve the performance of children with ADHD on the selective attention task. This was supported by data showing that children with ADHD responded more efficiently to targets when they were on-MPH than when they were off-MPH. Children were faster and more accurate when medicated.

When children with ADHD (on-MPH) were compared to their peers without ADHD, data indicated a different developmental trend for the two groups. Both groups showed an increase in efficiency as the children got older. When the younger children with ADHD were on-MPH, however, they were actually more efficient than their same age peers whereas the older children in the ADHD (on-MPH) group and the control group responded with similar efficiency. One explanation for this may be that all young children experience attention deficits to a certain extent due to immature attentional systems (Plude et al., 1994). It appears that the impact of MPH is sufficient to improve the younger children with ADHD to a level than surpasses their same age peers. Presumably then, if younger children in the control group were given MPH their performance would improve, although it would not be expected to improve to the same extent as children with ADHD in the younger group.

Children with ADHD (on-MPH) and children without ADHD exhibited more interference when both visual and auditory distracters are presented together or when visual distracters are presented alone. Children with ADHD (off-MPH), however, did not exhibit levels of interference that vary with distracter type and showed a greater deficit in all conditions than the control and the ADHD (on-MPH) groups. As stated earlier, children with ADHD (off-MPH) may experience overall task interference caused by the mere presence of distracters. If this explanation holds then the present data provides evidence that the administration of MPH reduces the overall impact of distracters making the pattern of interference for children with ADHD (on-MPH) more similar to controls. Thus, to optimize the learning environment, children with ADHD (off-MPH) would need to reduce any distraction from their environment which is impossible most of the time. If MPH is introduced, the overall impact of distracters is reduced. This should allow them to work more efficiently in environments where it is impossible to eliminate distracters.

Impulsivity has also been found to decrease when MPH is given to a child with ADHD (Malone & Swanson, 1993). Malone and Swanson (1993) examined the effects of MPH on impulsive responding in children with ADHD using a visual search word-matching task. Malone and Swanson (1993) defined impulsivity as the child blurting out an incorrect answer prior to giving a final answer. MPH reduced impulsivity in responding as well as the number of incorrect final responses for children with ADHD. In the present study children with ADHD (on-MPH) were more comparable to the control group than when they were off-MPH. Children with ADHD (off-MPH) had longer reaction times, than children with ADHD (on-MPH) or children without ADHD. This may indicate that children with ADHD were not responding impulsively when off-MPH, given that you would expect shorter reaction times with impulsive responding. Children with ADHD on-MPH, however may have been better able to control responding thereby improving their overall accuracy in comparison to when they were off-MPH.

In addition, when children with ADHD were on-MPH it did not change their response to the meaningfulness of the distracters. They continued to respond similarly to meaningful and unmeaningful stimuli which indicates that they were not building a strong association between the stimulus and response as was found with the children without ADHD. Although it is not clear why this might be, it may suggest that children with ADHD do not process distracters to the same level as control children. If, for example, the shirt distracters were not processed to the point of recognition then you would not expect more interference when the distracters were purses.

Overall, results indicated that the performance of children with ADHD improved when they were on-MPH as compared to when they were off-MPH. The following section will discuss the implications of development and MPH on ADHD.

Implications

As discussed in the introduction, ADHD has become a common diagnosis and many children with ADHD have difficulties in school. Understanding the nature of selective attention deficits can help us structure classrooms to minimize distraction. The fact that children with ADHD are slower overall in their processing and reaction times during the task provides us with knowledge that could be helpful in allowing children with ADHD a better opportunity to succeed. For example, a child with ADHD is given a test with 30 multiple choice and takes an extra 30 seconds per question because of processing difficulties. This extra 30 seconds per question (which does not appear to be a lot) adds up to an extra 15 minutes on that test. The 15 extra minutes that this child may need generally does not exist, which in turn can lead to frustration and test taking anxiety, which in turn may be displayed in acting out behaviours. Understanding that this may occur allows teachers and others working with children with attention problems the knowledge to provide the child with extra time to complete tasks. This may be a more practical solution than providing a testing environment without distraction, given the monetary resources required to isolate individuals for education. The example provided shows the practical aspects of selective attention in school, but there are many other areas of a child's life that may be affected similarly by problems of attention (e.g., sports, field trips, going to the mall).

Other implications of the present study are related to developmental findings that suggest children with ADHD do not perform as well as their same age peers on selective attention tasks. The fact that developmental effects were found for children with ADHD makes the practice of combining large age ranges together in a single group unacceptable.

Future studies of selective attention and no doubt other components of attention need to take developmental issues in to consideration when designing their studies.

The findings of this study indicated that for children with ADHD the nature of the distracter was less of an issue than the presence of distracters. Children without ADHD showed more differences to different types of distracters whereas children with ADHD showed a more generalized, overall distractibility to the task. Thus, children with ADHD experience the effects of distracters not only when they are present but also through retroactive and proactive interference. This finding would suggest that the presence of distracters need to be limited as much as possible in the learning environment of children in order to maximize their ability to process relevant information.

Methylphenidate, when used as a treatment for children with ADHD, decreases their distractibility relative to when they are not taking methylphenidate. This decrease in distractibility allows the child to maintain attention which is an important part of the learning process. Thus, medication during the school day may allow the child to process and encode more of the necessary material and lead to more productivity. Classroom performance has been found to improve for children with ADHD when they are taking MPH. DuPaul and Rapport (1993) explored the effects of MPH on children with ADHD. MPH produced a significant improvement in attention (on task behaviour) and academic efficiency, as well as improving teacher ratings of the child's behaviour from the baseline levels in children with ADHD. This improvement may in part be due to an improved ability to inhibit the impact of distracters.

It remains unclear whether the effects that MPH has on academic problems for children with ADHD are merely short-term gains or translate into long-term improvements in learning. In a review of the literature, Carlson and Bunner (1993) indicated that overall, studies have shown MPH to have strong positive effects on the short-term academic performance of children with ADHD, but long-term effects on academic achievement have not been documented. Carlson and Bunner (1993) believe that long term effects may not have been detected to date, due to methodological problems in the studies that are difficult to correct because of practical and ethical considerations. More research is needed on this front.

Future Studies

In the normative population, adults are more efficient at processing and responding to tasks than children. Because at least 30 percent of children with ADHD continue to have the disorder as adults (Kelly & Ramundo, 1996) it would be interesting to add an adult comparison group to see if the difference between ADHD and control groups narrow with age. Ideally, development would be studied using a longitudinal design. This would also allow for an assessment of the long-term impact of MPH.

Also, it would be beneficial to test the normative samples twice since the children with ADHD in this study were tested twice. Although this condition was counterbalanced with half the ADHD group being tested on medication first and half being tested off medication first the ADHD group scores may be inflated or deflated in comparison to the control group scores. Thus, future studies may want to look at the influence of practice on each group.

Furthermore, the present study was a computer task. Studies have indicated that children with ADHD are better at attending to television (e.g., Landau et al., 1992) and computers (e.g., Garber, Daniels-Garber, & Freedman-Spizman, 1996) than other tasks. Children with ADHD improved their performance on this task when they were taking MPH but they may not show the same improvements on a non-computer based task. Research on the implications of computer based education, ADHD, and MPH may also be useful. Furthermore, the present study investigated the impact of distracters on a visual task. These results may not be relevant to studies of auditory attention.

Finally, the impact of comorbid diagnosis with ADHD such as learning disabilities and oppositional defiant disorder should also be investigated. A more comprehensive look at ADHD, associated disorders and treatment effects is necessary to truly understand the nature of attention deficits in childhood.

Conclusion

Children with ADHD exhibited poorer performance than their same age peers without ADHD on a selective attention task. When children with ADHD were on-MPH, however, the gap in performance between them and their peers was lessened and sometimes disappeared. One explanation may be that children with ADHD may have a deficit in the encoding and processing component of the task which does not allow them to prepare efficiently for upcoming stimuli (Ceci & Tishman, 1984; Satterfield et al., 1990). This explanation, along with Higginbotham and Bartling's (1993) explanation that distracters affect the performance of a child with ADHD not only when the distracters are present but also following the removal of the distraction would explain why even on the no-distracter condition children with ADHD still do not perform as efficiently as children without ADHD and why the nature of distracters has less of an impact on children with ADHD. The present study also suggests that developmental effects are present for children with ADHD and children without ADHD although to a lesser extent for children with ADHD. Thus, children with ADHD demonstrate a developmental lag in visual selective attention that improves with the administration of MPH.

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Appendix A

Parental Consent Form: Control Group

Dear Parent/Guardian:

In a classroom we all wonder how children are affected by the distractions that may occur. For example, when a child is reading from a book how is he/she affected by two children talking next to him/her? We are writing to request permission for your child to participate in a study that examines how children are distracted by irrelevant information in their environment. The task we are using is designed to help us better understand the effects that visual and auditory distraction have on a child's attention. We are particularly interested in examining whether the presence of objects, sounds, or both is disruptive for children attempting to complete a task. Furthermore, we are interested in determining if the impact of distraction changes with age.

Children will be asked to watch various pictures of articles of clothing being presented on a computer screen and will be asked to respond to these pictures by pressing keys on a keyboard. Children may be distracted by surrounding pictures of articles of clothing on the computer screen, and/or they may be distracted by the names of the articles of clothing being played over a set of headphones. Children will complete the task during school hours at a time that is deemed appropriate by the teacher. The task will take approximately 15 minutes to complete, and children are free to withdraw at any time. In addition, we are requesting your permission for your child's teacher to complete a Conners' Teacher Rating Scale for your child. This measure assesses children's attentiveness in the classroom.

We want to emphasize that, for the children, this is a game not a test, with performance not being judged as good or bad. The children's responses on the task and scores on the Conners' Teacher Rating Scale are confidential, and are not part of any school record or grade. We are simply interested in the effects of distracters on children in varying age groups. Individual data will not be available.

We would appreciate it if you would sign the attached permission slip to permit your son/daughter to participate in this study and return it to the school. Our results will be shared with you in the form of a letter once the study has been completed. If you have any further questions about the study, please feel free to contact us at 542-2200, ext. #1116. Please retain the above portion as a copy of consent.

Sincerely,

Darlene Brodeur, Ph.D. Miranda S. Pond, BScH

Appendix B

Parental Consent Form: Hant's Community Hospital

Dear Parent/Guardian:

In a classroom we all wonder how children are affected by the distractions that may occur. For example, when a child is reading from a book, how is he/she affected by two children talking next to him/her? We are writing to request permission for your child to participate in a study that examines how children with attention problems are distracted by irrelevant information in their environment. This task is designed to help us better understand the effects that visual and auditory distraction have on a child's attention. We are particularly interested in examining whether the presence of objects, sounds, or both is disruptive for children attempting to complete a task. Furthermore, we are interested in determining if the impact of distraction changes with age.

Children will be asked to watch various pictures of articles of clothing being presented on a computer screen and will be asked to respond to these pictures by pressing keys on a keyboard. Children may be distracted by surrounding pictures of articles of clothing on the computer screen, and/or they may be distracted by the names of the articles of clothing being played over a set of headphones. We are requesting children to complete the task while medicated for attention problems and while on a regularly prescribed break from medication. Children will complete the task in your home, at Hant's Community Hospital, or at the Visual Attention Lab at Acadia University at a time that is convenient. The task will take approximately 15 minutes and each child will be asked to complete the task on two separate days. Children are free to withdraw at any time during the task.

We want to emphasize that, for the children, this is a game not a test, with performance not being judged as good or bad. The children's responses are confidential, and are not part of any school or hospital record. We are simply interested in the effects of distracters on children in varying age groups and the effect of medication on distraction. The children's responses are analyzed as a group. Individual data will not be available.

In addition, we are requesting your permission to ask your therapist the following questions: (1) Who gave the child the diagnosis of ADHD? And when? (2) Who initially prescribed medication for the child? And When?

We would appreciate it if you would sign the attached permission slip to permit your son/daughter to participate in this study and return it to us in the provided envelope. Our results will be shared with you in the form of a letter once the study has been completed. If you have any further questions about the study, please feel free to contact us at 542-2200, ext. 1116. Please retain the above portion as a copy of consent.

Sincerely,

Darlene Brodeur, Ph.D. Miranda S. Pond, BScH

Appendix C

Parental Consent Form: Attention Deficit Association of Nova Scotia

Dear Parent/Guardian:

In a classroom we all wonder how children are affected by the distractions that may occur. For example, when a child is reading from a book, how is he/she affected by two children talking next to him/her? We are writing to request permission for your child to participate in a study that examines how children with attention problems are distracted by irrelevant information in their environment. This task is designed to help us better understand the effects that visual and auditory distraction have on a child's attention. We are particularly interested in examining whether the presence of objects, sounds, or both is disruptive for children attempting to complete a task. Furthermore, we are interested in determining if the impact of distraction changes with age.

Children will be asked to watch various pictures of articles of clothing being presented on a computer screen and will be asked to respond to these pictures by pressing keys on a keyboard. Children may be distracted by surrounding pictures of articles of clothing on the computer screen, and/or they may be distracted by the names of the articles of clothing being played over a set of headphones. We are requesting children to complete the task while medicated for attention problems and while on a regularly prescribed break from medication (we will not be asking you to take your child off his or her medication for this study). Children will complete the task in your home, at the Bedford location of the Attention Deficit Association of Nova Scotia, or at the Visual Attention Lab at Acadia University at a time that is convenient. The task will take approximately 15 minutes and each child will be asked to complete the task on two separate days. Children are free to withdraw at any time during the task. In consideration of your travel and time you will be provided with $10.00 following the second testing session.

We want to emphasize that, for the children, this is a game not a test, with performance not being judged as good or bad. The children's responses are confidential, and are not part of any school or hospital record. We are simply interested in the effects of distracters on children in varying age groups and the effect of medication on distraction. The children's responses are analyzed as a group. Individual data will not be available.

In addition, we are requesting your permission to ask your therapist the following questions: (1) Who gave the child the diagnosis of ADHD? And when? (2) Who initially prescribed medication for the child? And When?

We would appreciate it if you would sign the attached permission slip to permit your son/daughter to participate in this study and return it to us in the provided envelope. Our results will be shared with you in the form of a letter once the study has been completed. If you have any further questions about the study, please feel free to contact us at 542-2200, ext. 1116. Please retain the above portion as a copy of consent.

Sincerely,

Darlene Brodeur, Ph.D. Miranda S. Pond, BScH

Appendix D

Directions For Task

The following explanation of the task will be given to each of the participants of the study:

I am going to get you to play a game on the computer. You are going to see pictures of different articles of clothing on the computer monitor and you are going to hear the names of different articles of clothing through the headphones. This is where you need to be looking when the game begins (point to the middle of the monitor). Sometimes you will see a picture of a tie (the child is shown a picture of a tie on an index card held up to the monitor) and when you see the tie press this key (point to key with a picture of a tie on it). Sometimes you will see a shirt (the child is shown a picture of a shirt on an index card held up to the monitor) and when you see the shirt press this key (point to key with a picture of a tie on it). Sometimes there will be three pictures on the computer monitor. When you see three pictures I want you the press the key that is like the picture in the middle. (One at a time, four index cards are shown to the child: (1) a shirt with a picture of a purse to the right and to the left, (2) a tie with a picture of a purse to the right and to the left, (3) a shirt with a picture of a tie to the right and to the left, (4) a tie with a picture of a shirt to the right and to the left). Following the presentation of each card the child is asked the following questions: What picture is in the middle? and Which key would you press if you saw these three pictures on the computer? You will also be asked to wear headphones during this game and from the headphones you will sometimes hear names of articles of clothing. Please ignore these sounds. Simply respond to the pictures as quickly and correctly as you can. Do you have any questions before we begin?

* Instructions may be repeated as necessary.

Appendix E

Summary of Post-hoc Testing Results

A. Reaction Time

Control Group and ADHD (off-MPH) Group

Main Effect of Distracter Modality	
Visual Distracters vs. Auditory Distracters	$Q(3,104)= 3.45$ $p<.05$
Visual Distracters vs. Visual + Auditory Distracters	$Q(3,104)= 0.65$ n.s.
Auditory Distracters vs. Visual + Auditory Distracters	$Q(3,104)= 4.09$ $p<.05$
Interaction of Group by Age	
Younger Age Group	
Control vs. ADHD	$Q(2,52)= 0.81$ n.s.
Older age Group	
Control vs. ADHD	$Q(2,52)= 5.30$ $p<.01$
Interaction of Distracter Modality by Age	
Younger Age Group	
Visual Distracters vs. Auditory Distracters	$Q(3,104)= 4.48$ $p<.01$
Visual Distracters vs. Visual + Auditory Distracters	$Q(3,104)= 0.75$ n.s.
Auditory Distracters vs. Visual + Auditory Distracters	$Q(3,104)= 5.52$ $p<.01$
Older age Group	
Visual Distracters vs. Auditory Distracters	$Q(3,104)= 0.54$ n.s.
Visual Distracters vs. Visual + Auditory Distracters	$Q(3,104)= 0.18$ n.s.
Auditory Distracters vs. Visual + Auditory Distracters	$Q(3,104)= 0.72$ n.s.
Interaction of Distracter Meaning by Group	
ADHD Group	
Meaningful Distracters vs. Unmeaningful Distracters	$Q(2,52)= 0.49$ n.s.
Control Group	
Meaningful Distracters vs. Unmeaningful Distracters	$Q(2,52)= 3.39$ $p<.05$

Control Group and ADHD (on-MPH) Group

Main Effect of Distracter Modality	
Visual Distracters vs. Auditory Distracters	$Q(3,104)= 4.56$ $p<.01$
Visual Distracters vs. Visual + Auditory Distracters	$Q(3,104)= 0.91$ n.s.
Auditory Distracters vs. Visual + Auditory Distracters	$Q(3,104)= 5.47$ $p<.01$

Interaction of Group by Age	
Younger Age Group	
Control vs. ADHD	Q(2,52)= 3.37 $p<.05$
Older age Group	
Control vs. ADHD	Q(2,52)= 2.78 n.s.

Interaction of Distracter Meaning by Group	
ADHD Group	
Meaningful Distracters vs. Unmeaningful Distracters	Q(2,52)= 0.06 n.s.
Control Group	
Meaningful Distracters vs. Unmeaningful Distracters	Q(2,52)= 4.49 $p<.01$

ADHD Group (off-MPH and on-MPH)

Main Effect of Distracter Modality	
Visual Distracters vs. Auditory Distracters	Q(3,44)= 4.19 $p<.05$
Visual Distracters vs. Visual + Auditory Distracters	Q(3,44)= 0.69 n.s.
Auditory Distracters vs. Visual + Auditory Distracters	Q(3,44)= 3.49 $p<.05$

B. Accuracy

Control Group and ADHD (off-MPH) Group

Interaction of Distracter Meaning by Age	
Meaningful Distracters	
Older Age Group vs. Younger Age Group	Q(2,52)= 7.22 $p<.01$
Unmeaningful Distracters	
Older Age Group vs. Younger Age Group	Q(2,52)= 2.70 n.s.

Interaction of Distracter Modality by Group by Age	
ADHD Group (younger)	
Visual Distracters vs. Auditory Distracters	Q(3,104)= 2.54 n.s.
Visual Distracters vs. Visual + Auditory Distracters	Q(3,104)= 1.45 n.s.
Auditory Distracters vs. Visual + Auditory Distracters	Q(3,104)= 4.00 $p<.05$
ADHD Group (older)	
Visual Distracters vs. Auditory Distracters	Q(3,104)= 1.46 n.s.
Visual Distracters vs. Visual + Auditory Distracters	Q(3,104)= 0.72 n.s.
Auditory Distracters vs. Visual + Auditory Distracters	Q(3,104)= 2.18 n.s.
Control Group (younger)	
Visual Distracters vs. Auditory Distracters	Q(3,104)= 0.67 n.s.
Visual Distracters vs. Visual + Auditory Distracters	Q(3,104)= 1.84 n.s.
Auditory Distracters vs. Visual + Auditory Distracters	Q(3,104)= 1.17 n.s.

Control Group (older)

Visual Distracters vs. Auditory Distracters $Q(3,104)= 0.09$ n.s.
Visual Distracters vs. Visual + Auditory Distracters $Q(3,104)= 0.35$ n.s.
Auditory Distracters vs. Visual + Auditory Distracters $Q(3,104)= 0.44$ n.s.

Control Group and ADHD (on-MPH) Group

Interaction of Distracter Meaning by Age

Younger Age Group

Meaningful Distracters vs. Unmeaningful Distracters $Q(2,52)= 2.35$ n.s.

Older Age Group

Meaningful Distracters vs. Unmeaningful Distracters $Q(2,52)= 2.08$ n.s.

ADHD Group (off-MPH and on-MPH)

Interaction of MPH by Age

On-MPH

Younger Age Group vs. Older Age Group $Q(2,22)= 3.65$ $p<.05$

off-MPH

Younger Age Group vs. Older Age Group $Q(2,22)= 1.20$ n.s.

Interaction of Distracter Modality by Age

Younger Age Group

Visual Distracters vs. Auditory Distracters $Q(3,44)= 1.28$ n.s.
Visual Distracters vs. Visual + Auditory Distracters $Q(3,44)= 0.89$ n.s.
Auditory Distracters vs. Visual + Auditory Distracters $Q(3,44)= 2.17$ n.s.

Older Age Group

Visual Distracters vs. Auditory Distracters $Q(3,44)= 2.70$ n.s.
Visual Distracters vs. Visual + Auditory Distracters $Q(3,44)= 0.51$ n.s.
Auditory Distracters vs. Visual + Auditory Distracters $Q(3,44)= 3.20$ n.s.

C. Efficiency

Control Group and ADHD (off-MPH) Group

Interaction of Distracter Meaning by Age

Younger Age Group

Meaningful Distracters vs. Unmeaningful Distracters $Q(2,52)= 4.06$ $p<.01$

Older Age Group

Meaningful Distracters vs. Unmeaningful Distracters $Q(2,52)= 0.32$ n.s.

Control Group and ADHD (on-MPH) Group

<u>Main Effect of Distracter Modality</u>	
Visual Distracters vs. Auditory Distracters	$Q(3,104)= 4.40$ $p<.01$
Visual Distracters vs. Visual + Auditory Distracters	$Q(3,104)= 1.29$ n.s.
Auditory Distracters vs. Visual + Auditory Distracters	$Q(3,104)= 5.69$ $p<.01$
<u>Interaction of Group by Age</u>	
Younger Age Group	
Control vs. ADHD	$Q(2,52)= 4.01$ $p<.01$
Older age Group	
Control vs. ADHD	$Q(2,52)= 2.31$ n.s.
<u>Interaction of Distracter Meaning by Group</u>	
ADHD Group	
Meaningful Distracters vs. Unmeaningful Distracters	$Q(2,52)= 0.78$ n.s.
Control Group	
Meaningful Distracters vs. Unmeaningful Distracters	$Q(2,52)= 4.86$ $p<.01$
<u>Interaction of Distracter Meaning by Age</u>	
Younger Age Group	
Meaningful Distracters vs. Unmeaningful Distracters	$Q(2,52)= 6.62$ $p<.01$
Older Age Group	
Meaningful Distracters vs. Unmeaningful Distracters	$Q(2,52)= 0.45$ n.s.

Appendix F

Summary of T-tests for Difference Scores

A. Reaction Time

Younger Control Group

Visual, Meaningful Condition	t (13)= 5.52, p <.01
Visual, Unmeaningful Condition	t (13)= 7.22, p <.01
Auditory, Meaningful Condition	t (13)= 4.87, p <.01
Auditory, Unmeaningful Condition	t (13)= 4.07, p <.01
Visual + Auditory, Meaningful Condition	t (13)= 3.65, p <.01
Visual + Auditory, Unmeaningful Condition	t (13)= 6.89, p <.01

Older Control Group

Visual, Meaningful Condition	t (17)= 4.03, p <.01
Visual, Unmeaningful Condition	t (17)= 4.83, p <.01
Auditory, Meaningful Condition	t (17)= 3.36, p <.01
Auditory, Unmeaningful Condition	t (17)= 2.84, p <.05
Visual + Auditory, Meaningful Condition	t (17)= 4.89, p <.01
Visual + Auditory, Unmeaningful Condition	t (17)= 3.74, p <.01

Younger ADHD (off-MPH) Group

Visual, Meaningful Condition	t (11)= 4.55, p <.01
Visual, Unmeaningful Condition	t (11)= 4.00, p <.01
Auditory, Meaningful Condition	t (11)= 3.84, p <.01
Auditory, Unmeaningful Condition	t (11)= 2.97, p <.05
Visual + Auditory, Meaningful Condition	t (11)= 7.29, p <.01
Visual + Auditory, Unmeaningful Condition	t (11)= 7.56, p <.01

Older ADHD (off-MPH) Group

Visual, Meaningful Condition	t (11)= 3.66, p <.01
Visual, Unmeaningful Condition	t (11)= 5.13, p <.01
Auditory, Meaningful Condition	t (11)= 4.71, p <.01
Auditory, Unmeaningful Condition	t (11)= 5.11, p <.01
Visual + Auditory, Meaningful Condition	t (11)= 4.54, p <.01
Visual + Auditory, Unmeaningful Condition	t (11)= 4.91, p <.01

Younger ADHD (on-MPH) Group

Visual, Meaningful Condition	t (11)= 5.72, p <.01
Visual, Unmeaningful Condition	t (11)= 4.14, p <.01
Auditory, Meaningful Condition	t (11)= 2.72, p <.05
Auditory, Unmeaningful Condition	t (11)= 3.91, p <.01
Visual + Auditory, Meaningful Condition	t (11)= 8.07, p <.01
Visual + Auditory, Unmeaningful Condition	t (11)= 4.30, p <.01

Older ADHD (on-MPH) Group

Visual, Meaningful Condition	t (11)= 4.68, p <.01
Visual, Unmeaningful Condition	t (11)= 5.35, p <.01
Auditory, Meaningful Condition	t (11)= 3.23, p <.01
Auditory, Unmeaningful Condition	t (11)= 2.84, p <.05
Visual + Auditory, Meaningful Condition	t (11)= 2.91, p <.05
Visual + Auditory, Unmeaningful Condition	t (11)= 3.06, p <.05

B. Accuracy

Younger Control Group

Visual, Meaningful Condition	t (13)= 0.18, n.s.
Visual, Unmeaningful Condition	t (13)= -0.42, n.s.
Auditory, Meaningful Condition	t (13)= 0.80, n.s.
Auditory, Unmeaningful Condition	t (13)= -0.33, n.s.
Visual + Auditory, Meaningful Condition	t (13)= 1.37, n.s.
Visual + Auditory, Unmeaningful Condition	t (13)= 0.21, n.s.

Older Control Group

Visual, Meaningful Condition	t (17)= -0.01, n.s.
Visual, Unmeaningful Condition	t (17)= 2.50, p <.05
Auditory, Meaningful Condition	t (17)= 0.52, n.s.
Auditory, Unmeaningful Condition	t (17)= 1.50, n.s.
Visual + Auditory, Meaningful Condition	t (17)= 0.32, n.s.
Visual + Auditory, Unmeaningful Condition	t (17)= 1.60, n.s.

Younger ADHD (off-MPH) Group

Visual, Meaningful Condition	t (11)= 0.15, n.s.
Visual, Unmeaningful Condition	t (11)= -0.42, n.s.
Auditory, Meaningful Condition	t (11)= 0.65, n.s.
Auditory, Unmeaningful Condition	t (11)= 0.62, n.s.
Visual + Auditory, Meaningful Condition	t (11)= 0.00, n.s.
Visual + Auditory, Unmeaningful Condition	t (11)= -2.05, n.s.

Older ADHD (off-MPH) Group

Visual, Meaningful Condition	t (11)= 0.46, n.s.
Visual, Unmeaningful Condition	t (11)= 0.00, n.s.
Auditory, Meaningful Condition	t (11)= -0.48, n.s.
Auditory, Unmeaningful Condition	t (11)= -0.61, n.s.
Visual + Auditory, Meaningful Condition	t (11)= -0.00, n.s.
Visual + Auditory, Unmeaningful Condition	t (11)= 1.49, n.s.

Younger ADHD (on-MPH) Group

Visual, Meaningful Condition	t (11)= -1.40, n.s.
Visual, Unmeaningful Condition	t (11)= -0.85, n.s.
Auditory, Meaningful Condition	t (11)= -1.55, n.s.
Auditory, Unmeaningful Condition	t (11)= -1.78, n.s.
Visual + Auditory, Meaningful Condition	t (11)= -0.56, n.s.
Visual + Auditory, Unmeaningful Condition	t (11)= -2.02, n.s.

Older ADHD (on-MPH) Group

Visual, Meaningful Condition	t (11)= -0.57, n.s.
Visual, Unmeaningful Condition	t (11)= -0.01, n.s.
Auditory, Meaningful Condition	t (11)= -2.15, n.s.
Auditory, Unmeaningful Condition	t (11)= -2.04, n.s.
Visual + Auditory, Meaningful Condition	t (11)= 0.21, n.s.
Visual + Auditory, Unmeaningful Condition	t (11)= -0.53, n.s.

Appendix G

Summary of Post-hoc Testing Results for Distracter Difference Analysis

Reaction Time

Control Group and ADHD (off-MPH) Group

Main Effect of Distracter Modality	
Visual Distracters vs. Auditory Distracters	Q(3,104)= 3.45 p<.05
Visual Distracters vs. Visual + Auditory Distracters	Q(3,104)= 0.65 n.s.
Auditory Distracters vs. Visual + Auditory Distracters	Q(3,104)= 4.09 p<.05
Interaction of Distracter Modality by Age	
Younger Age Group	
Visual Distracters vs. Auditory Distracters	Q(3,104)= 4.49 p<.01
Visual Distracters vs. Visual + Auditory Distracters	Q(3,104)= 0.75 n.s.
Auditory Distracters vs. Visual + Auditory Distracters	Q(3,104)= 5.23 p<.01
Older Age Group	
Visual Distracters vs. Auditory Distracters	Q(3,104)= 0.54 n.s.
Visual Distracters vs. Visual + Auditory Distracters	Q(3,104)= 0.18 n.s.
Auditory Distracters vs. Visual + Auditory Distracters	Q(3,104)= 0.72 n.s.
Interaction of Distracter Meaning by Group	
ADHD Group	
Meaningful Distracters vs. Unmeaningful Distracters	Q(2,52)= 0.47 n.s.
Control Group	
Meaningful Distracters vs. Unmeaningful Distracters	Q(2,52)= 3.92 p<.05

Control Group and ADHD (on-MPH) Group

Main Effect of Distracter Modality	
Visual Distracters vs. Auditory Distracters	Q(3,104)= 4.57 p<.01
Visual Distracters vs. Visual + Auditory Distracters	Q(3,104)= 0.91 n.s.
Auditory Distracters vs. Visual + Auditory Distracters	Q(3,104)= 5.48 p<.01
Interaction of Distracter Meaning by Group	
ADHD Group	
Meaningful Distracters vs. Unmeaningful Distracters	Q(2,52)= 0.06 n.s.
Control Group	
Meaningful Distracters vs. Unmeaningful Distracters	Q(2,52)= 4.79 p<.01

Interaction of Distracter Meaning by Age

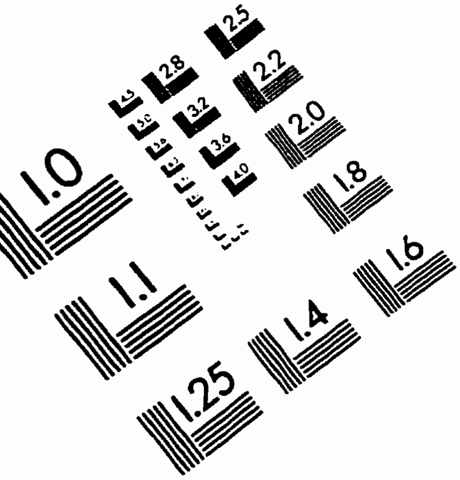
Younger Age Group	
Meaningful Distracters vs. Unmeaningful Distracters	$Q(2,52) = 4.92$ $p < .01$
Older Age Group	
Meaningful Distracters vs. Unmeaningful Distracters	$Q(2,52) = 0.63$ n.s.

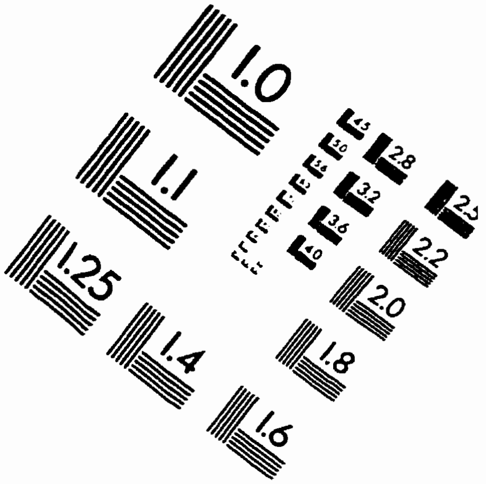
ADHD Group (off-MPH and on-MPH)

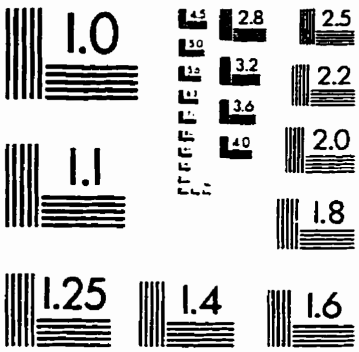
Main Effect of Distracter Modality

Visual Distracters vs. Auditory Distracters	$Q(3,44) = 4.19$ $p < .05$
Visual Distracters vs. Visual + Auditory Distracters	$Q(3,44) = 0.69$ n.s.
Auditory Distracters vs. Visual + Auditory Distracters	$Q(3,44) = 3.49$ $p < .05$

IMAGE EVALUATION TEST TARGET (QA-3)







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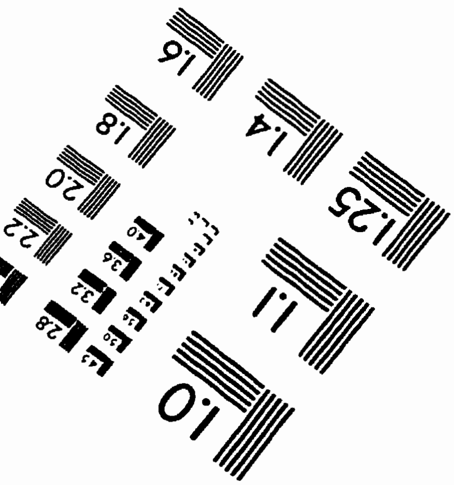

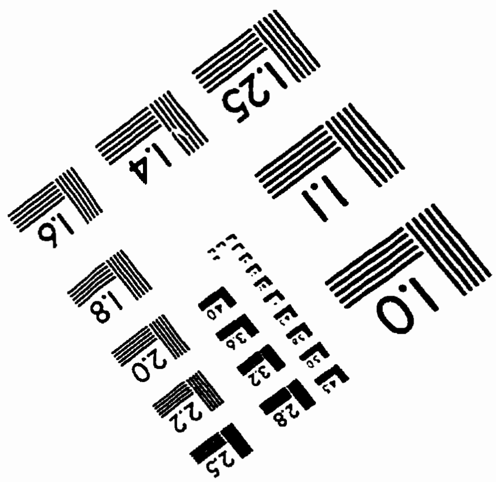

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