MANUAL TRACKING AND ATTENTION-DEFICIT/ HYPERACTIVITY DISORDER

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MANUAL TRACKING AND ATTENTION-DEFICIT/HYPERACTIVITY DISORDER

A Thesis

Presented for the Master of Arts Degree

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DEDICATION

This thesis is dedicated to my husband and daughter

Erick and Katelyn Segarra

and parents

Maria and Michael Underwood

who have continuously provided me the encouragement

and will to pursue my educational aspirations.

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Abstract

The literature suggests that children and adults with Attention-Deficit/Hyperactivity Disorder (AD/HD) demonstrate difficulties in motor timing related to synchronization and anticipation of motor output (Rubia, Noorloos, Smith, Gunning, & Sergeant, 2003). Studies have shown a high incidence rate of motor vehicle citations and accidents in the adult AD/HD population. Good driving requires success in motor tracking performance. Twenty-six children with AD/HD and 38 controls were studied to determine whether people with AD/HD demonstrate a deficit in manual tracking performance. Participants engaged in pursuit and compensatory perceptual-motor tracking tasks where they were asked to move in response to motion on a computer screen. No significant difference was found between AD/HD and control children in either pursuit or compensatory tracking. Also, there were no significant differences in motor tracking performance whether children with AD/HD were taking stimulant medication or not. However, children without AD/HD had significant improvement across trials in their performances in both their Root Mean Square (RMS) and *r* values while children without AD/HD only showed an improvement in their RMS values.

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CHAPTER 1

INTRODUCTION

Symptoms and Diagnosis

Attention-Deficit/Hyperactivity Disorder (AD/HD) has been linked to a variety of symptoms and deficits. It is associated with a combination of symptoms involving lack of attention, hyperactivity, and impulsiveness that would be considered "more frequent and severe" than what is developmentally appropriate (American Psychiatric Association, 1994, p.78). According to the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV), these symptoms typically manifest before the age of seven and must present themselves in at least two settings. Symptoms must provide a clear interference in the person's functioning and not be a secondary symptom to another mental disorder. In addition, people with AD/HD typically have difficulty completing tasks that require sustained attention, and their behaviors may be perceived as overactive or hyperactive. AD/HD appears to be more prevalent in males than females and affects approximately 3%-5% of school–age children (APA, 1994, pgs. 78-85). Currently, a leading theory in understanding AD/HD is one in which AD/HD is considered to be a disorder of inhibition (Barkley, 1997).

Inhibition is a Primary Deficit in AD/HD

Barkley (1997) reported that AD/HD is a disorder of behavioral inhibition. In his model he regards behavioral inhibition as 3 abilities: (a) ability to inhibit a prepotent response, (b) stop an ongoing response, and (c) run interference control. A disorder of these three abilities, according to Barkley, would be linked to a breakdown in four

specific executive functions: (a) working memory, (b) self-regulation of affect/motivation/and arousal, (c) internalization of speech, and (d) reconstitution- or analysis of goal directed behavior. Under Barkley's model, a breakdown of these four executive models would lead to further disruption in motor control, fluency, and syntax. It will be this impairment in motor control that will be the focus of this study.

Inhibition Support

A portion of Barkley's model was supported by Konrad, Gauggel, Manz, and Scholl (2000), who demonstrated that children with AD/HD had deficits in inhibitory control and prepotent response inhibition as compared to controls during a stop task and a delay task. Schachar, Tannock, Marriott, and Logan (1995) also reported a deficit in response inhibition in addition to a deficit in re-engagement of responses after inhibition had taken place in children with AD/HD who had a pervasive condition (pervasive meaning symptoms existing in both home and school, which qualifies as AD/HD under current DSM-IV standards). This disorder of inhibition extends to the area of vision research where it was found that adults with AD/HD had difficulty suppressing unwanted eye movements, or antisaccade conditions (Nigg, Butler, Huang-Pollack, & Henderson, 2002). Brain imaging techniques have also found evidence to support this hypothesis of a deficit in inhibition, particularly in the right frontostriatal hemisphere (Casey et al., 1997).

Prefrontal Cortex and Motor Pathways

A substantial amount of research in the area of AD/HD has focused on the motor pathways, specifically the prefrontal cortex of people with AD/HD (Bayliss &

Roodenrys, 2000). The motor circuit is said to project onto the frontal lobe located in the prefrontal cortex (Alexander, Delong, & Strick, 1986), which has been implicated in AD/HD. Rubia et al. (1999a), utilizing a visual motor inhibition task and a delay task, demonstrated that during an inhibitory task there was less brain activity in the left caudate nucleus and the right inferior prefrontal cortex. Rubia et al. thus hypothesized that the right prefrontal lobe is responsible for motor inhibition. An underactivation of this area according to Rubia et al. would demonstrate a difficulty with motor inhibition. Rubia et al., with their findings of an underactivated caudate nucleus in AD/HD, furthered support to the theory of a difficulty in motor processing. In addition, Overmeyer et al. (2001) discovered a deficit in gray matter, an important component in processing information, in the basal ganglia or motor circuit, particularly in the right globus pallidus and putamen.

The Caudate Nucleus Plays a Role in Inhibiting Information

The caudate nucleus, located in the basal ganglia or motor areas of the brain, has been reported to play a role in inhibiting motor responses (Rauch & Savage, 1997; Semrud-Clikeman et al., 2000). It has also been implicated in motor execution of visual-motor tracking tasks (Aldridge, Anderson, & Murphy, 1980). In studying the symmetrical differences between the caudate nuclei of boys with AD/HD some researchers have found significant differences between the caudate regions of boys with AD/HD and control groups. Semrud-Clikeman et al. reported that children with ADD/H scored significantly worse on measures of inhibition, particularly those that demonstrated a reversed caudate asymmetry (Left<Right). Semrud-Clikeman et al. compared those that showed this reversed caudate asymmetry to Stroop effect results, a task that measures

inhibition. They found that those with this difference in asymmetry demonstrated a poorer performance on the Stroop task than those that did not. Those that performed significantly worse on sustained attention tasks also showed through MRI analysis to have less white matter in the right hemisphere. Other studies have also found a similar pattern of reversed asymmetry of the caudate or a lack of the regular right>left pattern of asymmetry in participants with a diagnosis of AD/HD (Hynd et al., 1993; Mataro, Garcia-Sanchez, Junque, Estevez-Gonzalez, & Pujol, 1997). Castellanos et al. (1996) also discovered a difference; they did not find the regular decrease in the volume of the caudate that has been typically been found in normal subjects, nor was there found the regular increase in lateral ventricle volume. These findings of brain differences in the caudate nuclei of people with AD/HD lend support to a possible deficit in motor control for people with AD/HD.

Individuals with AD/HD Show Motor Control Impairments

Motor difficulties have been found in studies investigating participants with AD/HD. Rubia, Taylor, Taylor, and Sergeant (1999b) found that male children with hyperactivity demonstrate a deficit in timing their motor output related to synchronization and anticipation of a stimulus and self-regulation. However this was conflicted in a follow-up study done by Rubia et al. (2001), where a delay in motor timing was not found in participants with AD/HD, only a deficit in motor inhibition. Rubia et al. attributed this to the possibility of this deficit being presented in the context of different motor tasks. In another study, Rubia, Noorloos, Smith, Gunning, & Sergeant (2003) found the same differences in synchronization and anticipation as was found in their

earlier 1999 study. These differences in variability were found in both a community and clinical sample. This study also indicated that methylphenidate (Ritalin), a stimulant medication, improves variability in both of the aforementioned difficulties as well as increasing the speed in which synchronization could be reached. These motor timing tasks would incorporate another brain region responsible for motor coordination, specifically the cerebellum.

It has been shown that the cerebellum is implicated in the role of motor coordination as well as input and output to the cerebral cortex (Miall, Reckess, & Imamizu, 2001; Tamada, Miyauchi, Imamizu, Yoshioka, & Kawato, 1999). Castellanos et al. (1996) found that boys with AD/HD had significantly smaller total cerebral volume, a smaller globus pallidus, cerebellum, and right anterior frontal region. In a follow-up study, Berquin et al. (1998) found a 6.1% decrease in cerebral volume, a 3.8% decrease in cerebellar volume, and an 8.5% decrease in vermal volume, as compared with controls. This time, the decrease in cerebellar volume did not maintain significance after total cerebral volume was controlled. However, these findings still remain interesting. In both studies, the overall cerebral volume remained significantly decreased, suggesting a biological difference between boys with AD/HD and boys without the disorder. The finding of a smaller cerebellar vermal volume was also found by Mostofsky, Reiss, Lockhart, and Denckla (1997), lending support to the findings of motor deficits or differences in people with AD/HD.

The cerebellar activity has specifically been implicated in coordination during manual tracking tasks, with cerebellar activity showing significance during large

movement errors and during visual-motor coordination when performance errors were low, producing a parametric relationship (Miall et al., 2001). With such abnormalities being found in cerebellar vermal volume, it would be expected that people with AD/HD would exhibit some difficulty with a manual tracking task.

Manual Tracking

Manual motor tracking is a method that is used to measure visual-motor coordination. Manual tracking is measured with a task that presents some form of movement stimulus, and having a participant provide a form of motor output to match the input stimulus. Any difference between the stimulus input and the motor output is error. The participant's goal in these tasks is to minimize the error as much as possible (Adams, 1989, pg. 250).

There are two different types of motor tracking tasks: pursuit and compensatory. In a pursuit task, the participant may attempt to follow a visible path or line with as little error as possible. The amount of error that results is measured and collected as the dependent variable. In a compensatory task, a participant attempts to control or negate pre-existing error; it does this through the act of correction by working against an unknown force that is trying to push it away from the zero error point (Adams, 1989, pgs. 257-262). Driving is a good example of pursuit and compensatory tasks. When a person is driving, they are following along a designated path and attempting not to veer outside of the designated line boundaries (pursuit) (Adams, 1989, pgs. 249 & 258). A different situation might be a person who is driving with bad steering alignment and is trying to

stay in the middle of his or her lane, but has to constantly correct for the force that is pulling his or her vehicle off to the right side of the road (compensatory).

Driving and AD/HD

It has been found that adolescents and adults with AD/HD have higher incidences of driving citations to include speeding, more automobile crashes, and are more likely to have their licenses suspended or revoked (Barkley et al., 1995; Barkley, Murphy, & Kwasnik, 1996; Cox, Merkel, Kovatchev, & Seward, 2000; Nada-Raja et al., 1997). In the study conducted by Barkley et al. (1996), adults with AD/HD were found to have more than five times more motor vehicle citations than the control group and were significantly more likely to be deemed as "at fault" in an accident. This was evidenced not only by their traffic records, but also in a driving simulation tracking task. In their study, Barkley et al. (1996) accounted for driving knowledge by providing a driving knowledge test to both AD/HD and control groups and found no significant difference in their driving knowledge. They concluded that the higher number of driving mishaps for the AD/HD group was due to performance and not due to driving knowledge.

Present Study

Due to the research findings of poor driving performance, combined with the structural abnormalities (most specifically the cerebellum of AD/HD groups), and difficulties with motor timing, the most logical follow-up study would be one of manual tracking at an early age and in its most simple form. This would help to determine if the tracking deficits found in a driving task could be basic in nature and extend to other manual skills which may involve motor tracking coordination. The purpose of this study

was to determine whether children with AD/HD exhibit a skill deficit in motor tracking tasks. Motor tracking was studied using a pursuit and a compensatory task in order to determine if the inhibitory motor deficit shown by children with AD/HD is actually a product of an earlier deficit in tracking. It was predicted that children with AD/HD would exhibit more error in motor tracking than controls. It was also predicted that all participants would perform better on the pursuit task as opposed to the compensatory task.

CHAPTER 2

METHOD

Participants

Participants were 70 children total, 30 children with AD/HD, and 40 control children, ages 9 through 12. AD/HD diagnosis was determined by parent or school report, subtype was not specified. Three children were eliminated due to an ADD diagnosis being provided without parent or school confirmation of an AD/HD diagnosis. Any child whose data resulted in more than one trial being 2 standard deviations away from the mean was also eliminated. This resulted in 2 control participants and 1 child with AD/HD being eliminated from the study. The final total of participants was 26 children with AD/HD and 38 control children. Of the 26 children with AD/HD, 20 were on stimulant medication and 6 were medication-free. All children with AD/HD were free from comorbidity of other diagnoses. All control children were free from any diagnosis. All children were recruited from five schools in the Montgomery County School System.

Apparatus

A laptop with a mouse was used as well as two previously developed computer programs designed to measure motor pursuit and compensatory skills (loaned for this study by Dr. Charles Woods).

Stimuli

The main stimulus in these tasks was a small sailboat which moved from left to right by virtue of the computer.

In the pursuit tracking task there was a sinusoidal pattern of dots on the screen. The computer moved the sailboat from left to right at a constant rate; the participants controlled the sailboat in the vertical dimension. The participants were instructed to follow the sinusoidal pattern on the screen (see Figure 1).

In the compensatory task, there was a horizontal straight line in the center of the computer screen (see Figure 2). The computer moved the sailboat from left to right, as in the pursuit task, but also moved it vertically in a sinusoidal pattern as a form of unseen resistance. The participant was instructed to move the sailboat vertically to keep it on the horizontal line while the resistance ("wind") attempted to move the sailboat off course. Both the pursuit path and the unseen compensatory force was in the shape of a sinusoid with 4 ½ cycles. Participants were not able to vary the speed of the sailboat in each task. Both pursuit and compensatory tasks have been shown to be good measures of manual tracking in past research.

Design

This was a Quasi-experimental mixed design. Groups included a group with AD/HD vs. a control group for the between factor comparison. Within factors comparisons were between pursuit performance and compensatory performance. Participants' performance were measured based on the amount of error between path position and participant's actual sailboat position. Conditions were counterbalanced. Each subject participated in two trials per task.

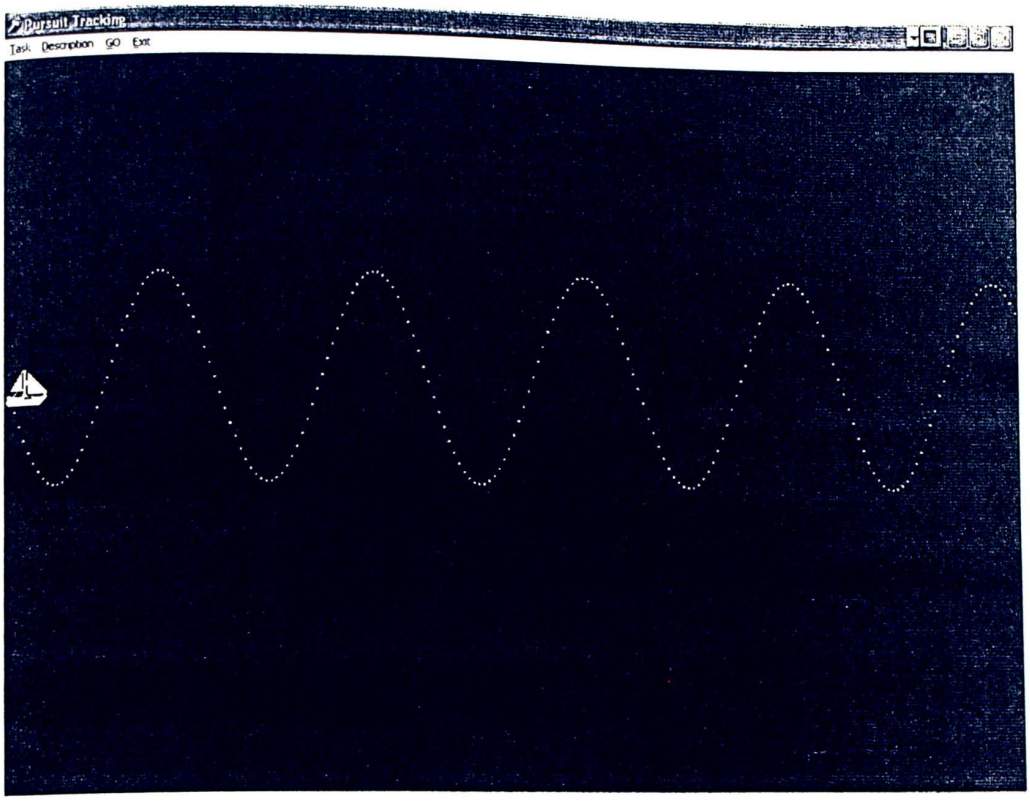

Figure 1. Pursuit tracking task as seen by participants.

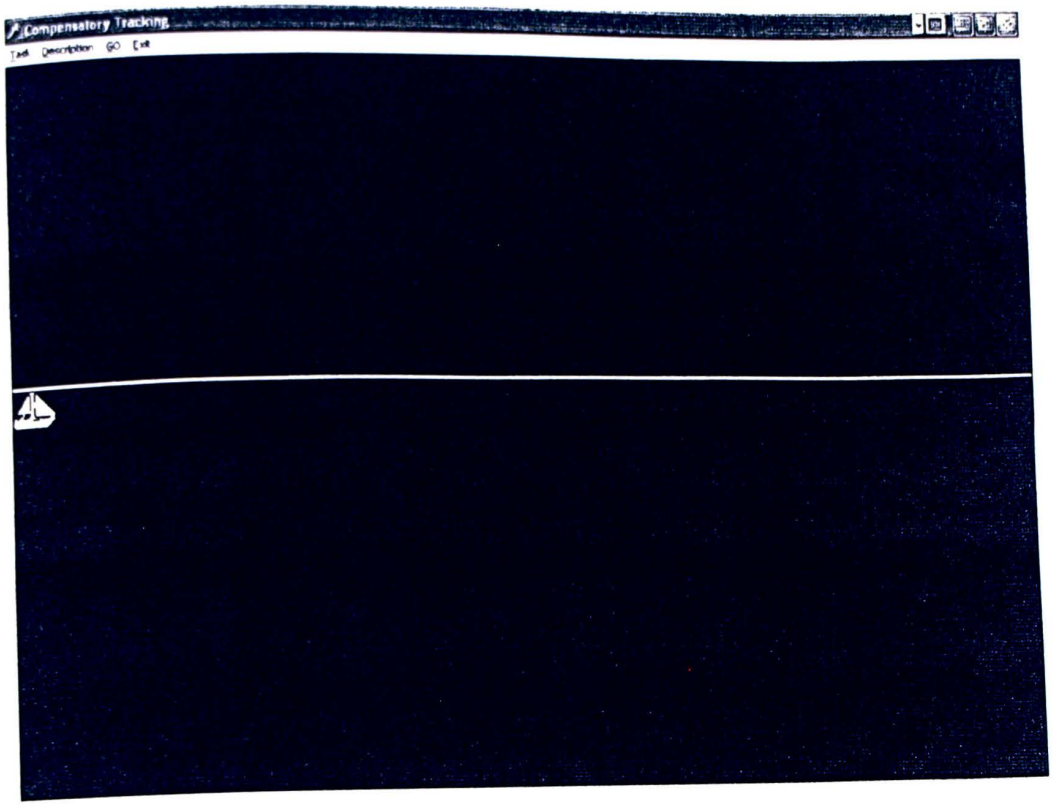

Figure 2. Compensatory tracking task as seen by participants

Procedure

All participants' parents signed informed consent in order to be included in the study. For the pursuit task, participants sat individually in front of a computer screen and were instructed to keep the center of the sailboat on the dotted path of buoys moving their computer mouse up or down while the computer moved their sailboat across the screen.

For the compensatory task, participants sat in front of a computer screen and were instructed to correct the center of the sailboat by moving the computer mouse up and down so that it stayed on top of the horizontal line while a force "wind" continuously pushed it off path. Participants conducted two trials of each task. Participants chose their computer mouse dominant hand to conduct the trials.

CHAPTER 3

RESULTS

Root Mean Square (RMS)

The data collected in all tasks were error measures. The Root Mean Square (RMS), or the standard deviation of error made between the input (correct position points) and output (participant's responses), constituted the first error measure (pursuit - how close to the buoys participants placed the boat; compensatory - how close they placed the boat to the straight line). A RMS score was calculated for each trial of each task. A Pearson correlation coefficient (r), the second error measurement, was calculated in order to determine whether the participants' movement of the boat correlated with the stimulus presented (pursuit - boat to buoy; compensatory - boat to line when "wind" was added). The boat vs. buoy positions were calculated across time in the pursuit task and the boat position vs. the wind resistance were measured on the compensatory task.

Means and Standard Deviations were calculated across conditions. Figure 3 shows mean RMS values for children with AD/HD and Figure 4 shows mean RMS values for children without AD/HD across tasks. An Analysis of Variance (ANOVA) was conducted to determine if there was a significant difference in motor tracking performance, as measured by RMS values for children with AD/HD versus children without AD/HD. No significant difference was found between groups in their RMS error values, $F(1, 62) = 0.0004, p \geq 0.05$. Further analysis was conducted to determine whether there was a difference in the tasks (pursuit vs. compensatory) performed across

groups. This analysis determined there was not a significant difference $F(1, 62) = 0.505$, $p \geq 0.05$. There was, however, a significant effect of trial (improvement) across groups $F(1, 62) = 57.164, p \leq 0.05$. Interaction effects were analyzed and no significant interactions were found [group vs. task $F(1, 62) = 2.506$, $p \geq 0.05$; group vs. trial $F(1, 62) = 0.682, p \geq 0.05$; task vs. trial $F(1, 62) = 1.750$, $p \geq 0.05$; group vs. task vs. trial $F(1, 62) = 0.536, p \geq 0.05$]. Data from children with AD/HD were analyzed to determine whether medication played a role in the results. The group was separated into medicated (20 participants) and non-medicated (6 participants). Again, for children with AD/HD there was no effect of medication $F(1, 24) = 3.735, p \geq 0.05$. They did not perform differently on task $F(1, 24) = 1.161, p \geq 0.05$. They did, however, perform better dependant on trial $F(1, 24) = 17.212, p \leq 0.05$. There were no significant interaction effects [task vs. trial $F(1, 24) = 1.058, p \geq 0.05$; task vs. trial vs. medication $F(1, 24) = 1.463, p \geq 0.05$]. For children without AD/HD, they did not perform differently on task $F(1, 37) = 0.508, p \geq 0.05$. They did perform differently with trial $F(1, 37) = 36.798, p \leq 0.05$. There was not a significant interaction between task and trial $F(1, 37) = 2.220, p \geq 0.05$.

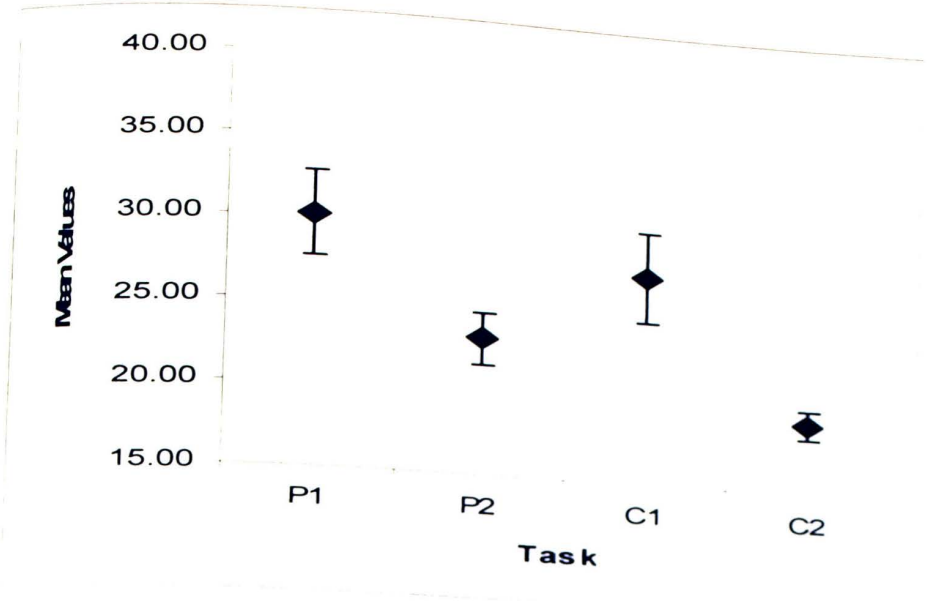

Figure 3. Mean representation for RMS values on pursuit (P1, P2) and compensatory tasks (C1, C2) for children with AD/HD.

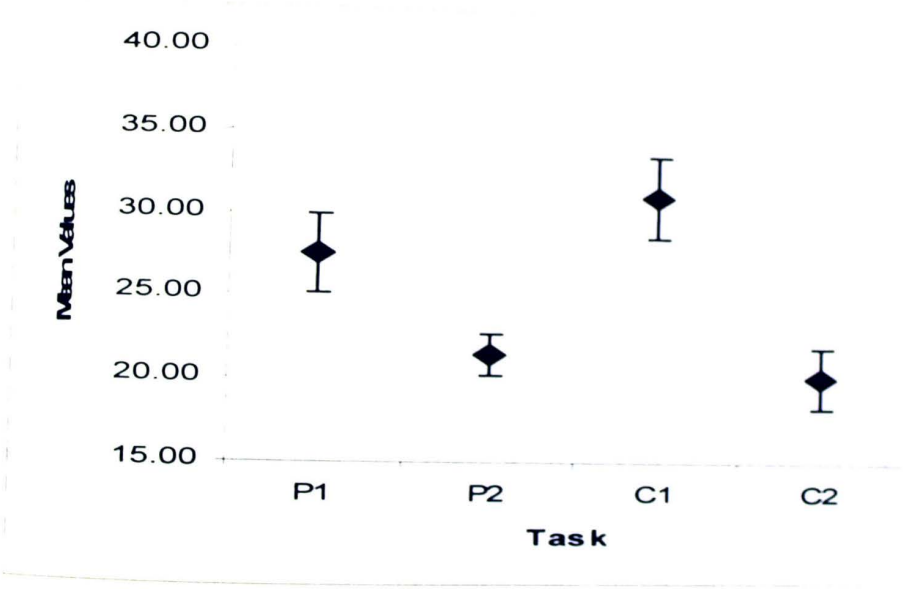

Figure 4. Mean representation for RMS values on pursuit (P1, P2) and compensatory tasks (C1, C2) for children without AD/HD.

Correlation (r)

Figure 5 shows mean *r* values for the pursuit task for children with AD/HD and Figure 6 shows mean *r* values for the pursuit task for children without AD/HD. Figure 7 shows the compensatory task mean *r* values for children with AD/HD and Figure 8 shows mean *r* values for children without AD/HD on the compensatory task. An ANOVA was also conducted to determine if there was a significant difference in *r* values across tasks between children with and without AD/HD. No significant difference was found across groups $F(1, 62) = 0.512, p \geq 0.05$. There was also not a significant difference in task $F(1, 62) = 1.836, p \geq 0.05$. Further analysis did indicate a significant improvement of trial $F(1, 62) = 5.769, p \leq 0.05$. There were, however, no significant interactions found [group vs. task $F(1, 62) = 0.065, p \geq 0.05$; group vs. trial $F(1, 62) = 0.325, p \geq 0.05$; task vs. trial $F(1, 62) = 0.187, p \geq 0.05$; group vs. task vs. trial $F(1, 62) = 0.521, p \geq 0.05$]. Data was then analyzed to determine whether medication played a role in the results. For children with AD/HD, medication did not play a factor in the results $F(1, 24) = 0.126, p \geq 0.05$. Their *r* values were not affected by task $F(1, 24) = 0.100, p \geq 0.05$. Unlike with RMS, there was not a significant improvement with practice $F(1, 24) = 0.581, p \geq 0.05$. There were no significant interaction effects [task vs. medication $F(1, 24) = 0.562, p \geq 0.05$; trial vs. medication $F(1, 24) = 0.003, p \geq 0.05$; task vs. trial $F(1, 24) = 0.001, p \geq 0.05$; task vs. trial vs. medication $F(1, 24) = 0.007, p \geq 0.05$]. For children without AD/HD, they did not perform differently given the task $F(1, 37) = 1.089, p \geq 0.05$. They also did perform differently dependant on the trial $F(1, 37) = 8.539, p \leq 0.05$. There was not a significant interaction effect $F(1, 37) = 1.592, p \geq 0.05$.

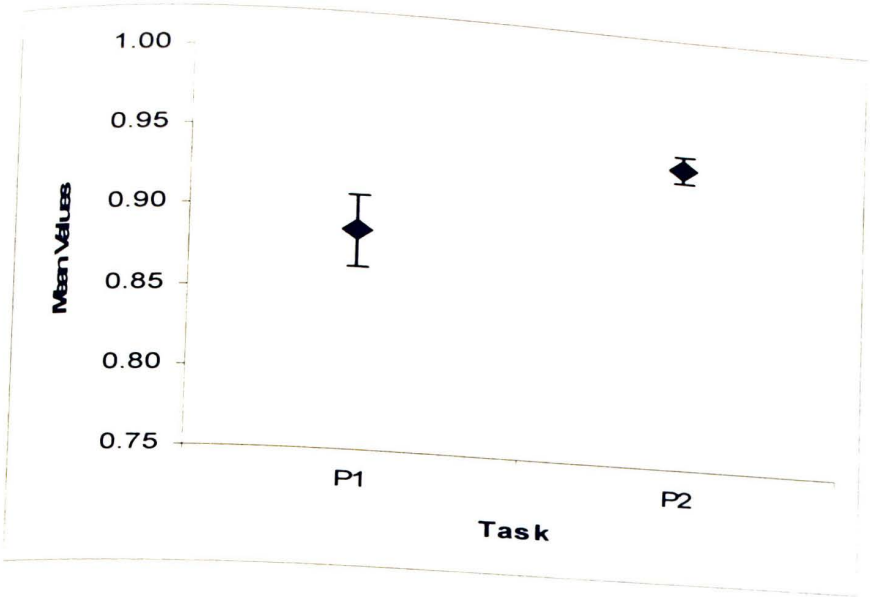

Figure 5. Mean representation for *r* values on pursuit task (P1, P2) for children with AD/HD.

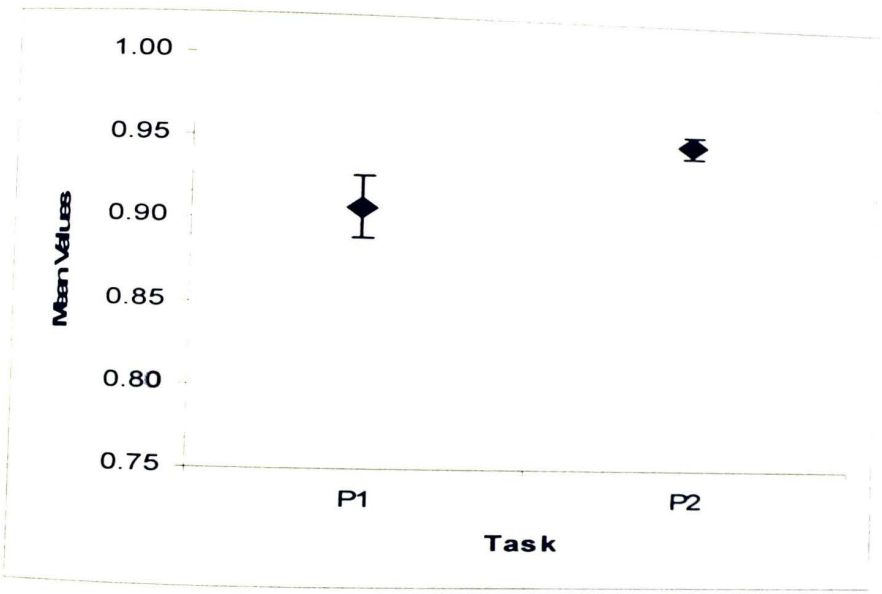

Figure 6. Mean representation for *r* values or pursuit task (P1, P2) for children without AD/HD.

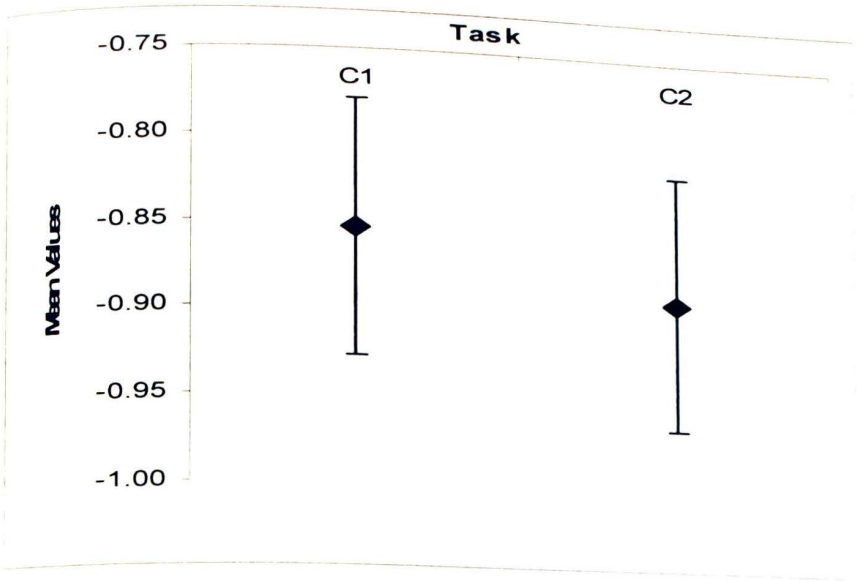

Figure 7. Mean representation for *r* values on compensatory task (C1, C2) for children with AD/HD.

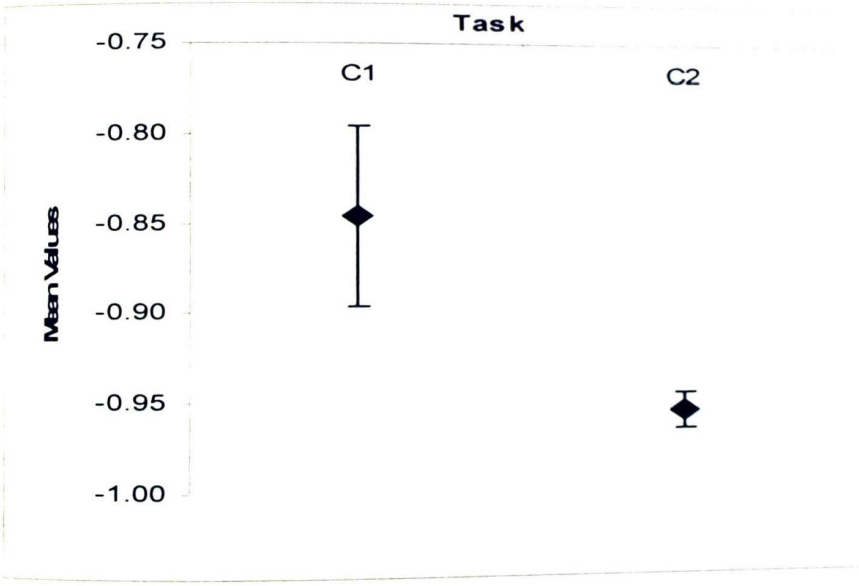

Figure 8. Mean representation for *r* values on compensatory task (C1, C2) for children without AD/HD.

CHAPTER 4

DISCUSSION

Children with AD/HD have been shown to have difficulties with a combination of symptoms to include: inattention, impulsiveness, and hyperactivity (APA, 1994, pgs. 78-85). Research has shown that children with AD/HD perform poorer on tasks related to motor inhibition (Casey et al., 1997; Konrad et al., 2000; Nigg, et al., 2002; Schacher et al., 1995). Previous research has also shown that people with AD/HD have difficulties with motor timing and synchronization (Rubia et al., 1999b).

Adolescents with AD/HD have been shown to have poorer driving records to include more citations than adolescents without AD/HD (Barkley et al., 1995; Barkley et al., 1996; Cox et al., 2000; Nada-Raja et al., 1997). Motor tracking skills are used in driving. This study investigated motor tracking performance between children with AD/HD and without AD/HD.

A difference in motor tracking was not found between children with AD/HD and children without AD/HD utilizing pursuit and compensatory motor tracking tasks. Children in both groups demonstrated similar results in performance regardless of whether they were doing a pursuit or compensatory task. It was also determined that stimulant medication was not a factor in the results for children with AD/HD.

Children overall, however, did improve their performance with practice. Children without AD/HD showed a significant improvement in their RMS and r values, while children with AD/HD demonstrated a significant improvement in their RMS values but

not for their r values. This underlying discrepancy in trial performance of tracking may also be related to their differences in driving noted in previous studies (Barkley et al., 1995; Barkley et al., 1996; Nada-Raja et al., 1997). An example of this might be a person attempting to drive down a winding road. Their RMS value would be how well they were able to stay in their lane, their r value would be how well they responded to curves in the road. In this example, any person with or without AD/HD would improve upon their ability to stay in the road. The person without any diagnoses would also improve in keeping up with the curves in the road as they came upon them. The person without AD/HD theoretically would not. Keeping in mind the fact that both groups do improve upon their ability to stay in the road, it stands to reason that the person with AD/HD although they may not improve in keeping up with the curves, will not necessarily run off the road.

Tracking, of course, is only one small aspect of driving and other factors such as environmental ones, either personal history or physical surroundings or difficulties with tasks requiring multiple attentional needs (i.e. pushing the gas peddle, watching the stoplights, keeping the car on a path) cannot be ruled out. This study differs from previous motor timing studies in that it provides an element of continuous motor tracking which may be the reasoning behind the differences in results. It should be noted, however, that 77% of the children with AD/HD were taking stimulant medication continuously. According to Rubia et al. (2003) this could greatly enhance the performances in a task related to motor timing and synchronization. This study has strong elements of both. Previous research has also shown stimulant medication to

improve upon driving performance in adolescents with AD/HD (Cox et al., 2000). Further research in the area of manual tracking with a more equally distributed group of non-medicated children with AD/HD is needed in order to further decipher the reasons behind such differences in trial performances on manual tracking tasks.

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