ANALYZING THE CURSOR TRAJECTORY AND EMOTION OF POTENTIAL ADULT ATTENTION-DEFICIT/HYPERACTIVITY DISORDER IN THE GO/NO-GO TASK

An Undergraduate Research Scholars Thesis

by

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ABSTRACT

Testing the Cursor Trajectory and Emotion of Potential Adult Attention-Deficit/Hyperactivity Disorder in the Go/No-Go Task

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Attention-deficit/hyperactivity disorder (ADHD) is a common and underdiagnosed mental disorder that affects more than 1 in 10 (11%) of U.S children, and about 60% of children with ADHD become adults with ADHD (Visser et al., 2014; Barkley, Fischer, 2010). The diagnostic methods used today are designed for adolescents; as a result, primary care physicians encounter significant difficulties when diagnosing ADHD in adults. In the proposed project, I aim to clarify main characteristics of adult ADHD by analyzing their symptoms with respect to a group of higher order cognitive abilities known as executive function by scrutinizing the relationship among impulsivity, emotion, and motions. It is known that ADHD patients have a noticeable deficiency in the ability to inhibit emotions, also known as emotional impulsivity. Research indicates that people's emotional states are reflected in their body motions. In this regard, I hypothesize that executive control is manifested in body motions (e.g., directed hand movement) in adult ADHD patients. To test this hypothesis, I will measure the movements of the computer cursor in the go/no-go task, and compare the cursor movement patterns of those who

are vulnerable to ADHD and those who are not. If found successful, it would help primary care physicians better diagnose ADHD for adults.

NOMENCLATURE

ADHD	Attention-Deficit/Hyperactivity Disorder
CAARS	Connors Adult ADHD Rating Scales
DSM-5	Diagnostic and Statistical Manual of Mental Disorders
DESR	Deficient Emotional Self-Regulation
EIS	Emotional Impulsivity Scale
EFs	Executive Functions
WRAADS	Wender-Reimherr Adult Attention Deficit Disorder Scale

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CHAPTER I

INTRODUCTION

The current "gold standard" method of diagnosis for Attention-deficit/hyperactivity disorder (ADHD) closely follows the guidelines in the fifth edition of the *Diagnostic and Statistical Manual of Mental Disorders* (DSM-5). However, the symptoms involved in this manual are still based on those originally established for children and adolescents ages 4-17 and not specifically for adults (McGough & Barkley, 2004). Another problem that primary care physicians face when diagnosing ADHD are the comorbidities that may arise. The physician has to carefully examine the symptoms to determine the overlap between ADHD and other mental health disorders. This may prove difficult and problematic for the physician in some cases.

Importance

There was a survey done on 400 primary care physicians who commonly treat adults with mental health disorders. They reviewed their knowledge and diagnostic/treatment preferences of these mental health disorders along with ADHD (Adler, Shaw, Sitt, Maya, & Morril, 2009). Many primary care physicians claim that they are much more knowledgeable in other mental health disorders than ADHD, and additionally, 85% of the primary care physicians are said to feel that a validated screening tool is necessary to help in the diagnosis of adult ADHD (Adler, Alperin, 2014). In this regard, it is critical to more accurately diagnose ADHD. A study done on seven symptoms of emotional impulsivity (impatient, quick to anger, easily frustrated, overreact, easily excited, lose temper, and touchy/annoyed) were conducted on adults with ADHD along with a community control group, and the frequency of these symptoms were significantly higher (Barkley, Murphy, & Fischer, 2008). As seen in a study done by Yamauchi and Xiao (2016),

induced emotions give rise to altered cursor trajectory patterns in choice-reaching behavior. By trying to elicit these emotions and analyzing their impulsivity through a series of cues, I aim to detect a pattern between patients with ADHD by scrutinizing their impulsivity, emotion, and cursor motion in the go/no-go task.

CHAPTER II

EMOTIONAL IMPULSIVITY

Attention-deficit/hyperactivity disorder (ADHD) as defined by DSM-5 is a neurodevelopmental disorder that is characterized by impairment to inattention, disorganization, and/or hyperactivity-impulsivity (American Psychiatric Association, 2013). However, Barkley and Murphy (2009) mention that emotional impulsivity has been conceptualized in ADHD dating back to 1798 with the first medical description of ADHD by Crichton, and later by Still (1902) on a group of English children, and finally Wender in 1976. Reviews of scientific literature show clinical and empirical evidence, and suggest that emotional impulsivity and deficient emotional self-regulation are also core symptoms of ADHD (Barkley, Murphy, 2009; Barkley, Fischer 2010; Martel, 2009). Overall, adults with ADHD were characterized with impatience, low frustration tolerance, hot-temperedness, quickness to anger, irritability, and to display your emotions much quicker than others. This is especially apparent in the study done by Barkley and Fischer (2010) where they evaluated children (N = 135) with ADHD and reevaluated them in adulthood (Fig. 1). Those who still had ADHD in adulthood had a high percentage of emotional impulsivity symptoms. However, those who were recovering from ADHD in adulthood were also recovering from emotional impulsivity symptoms and had lower percentages, but percentages were still higher than the control group. They concluded that emotional impulsivity was as much a core component of ADHD as the two traditional ADHD symptoms inattention and hyperactivity (Barkley, Fischer, 2010).

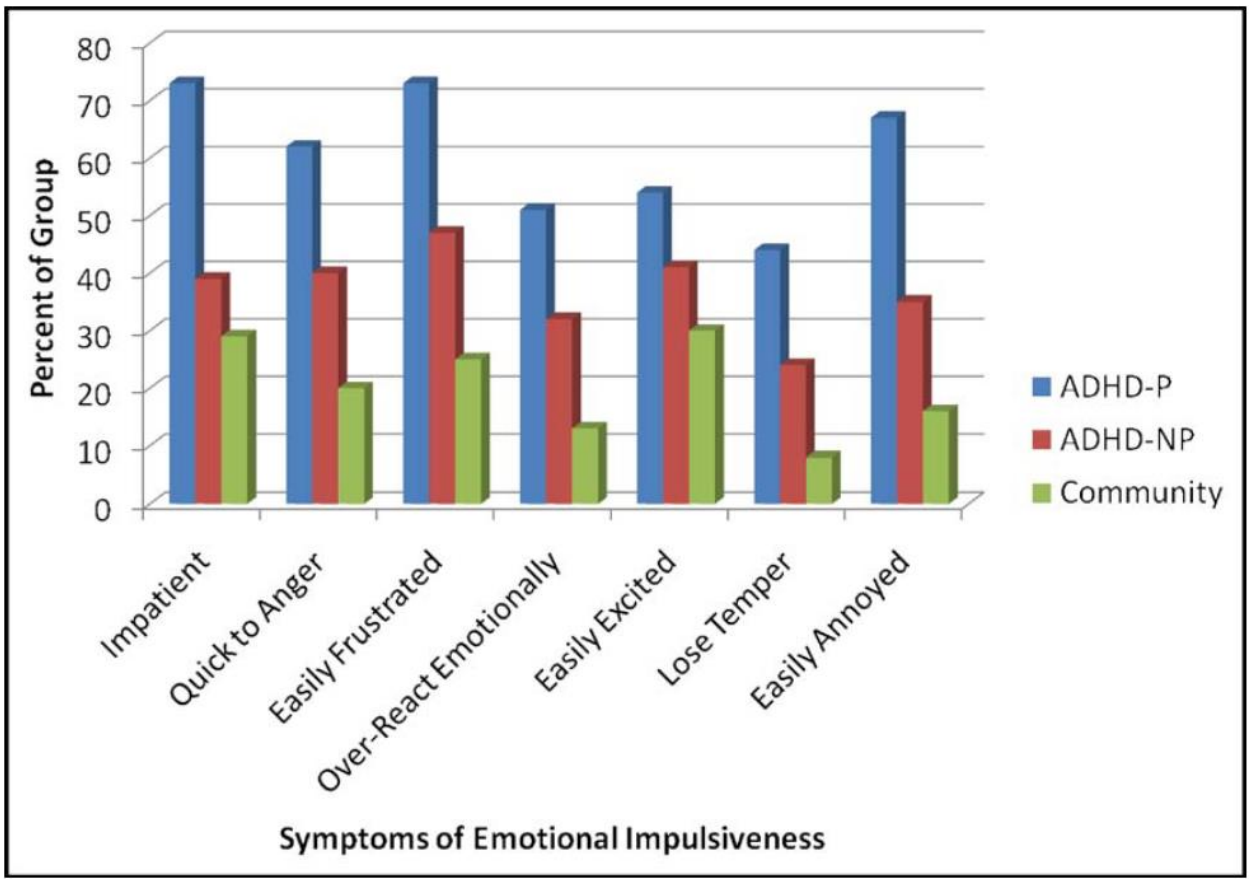

Fig. 1. Symptoms of Emotional Impulsiveness in ADHD-P = ADHD persistent (N=55); ADHD-NP = ADHD non-persistent N=80); and community (N=75). From: (Barkley, Fischer, 2010).

Although emotional dysregulation is a well-known problem in children (Barkley 2014), no longitudinal studies exist that have investigated the development of emotional problems other than the core symptoms of ADHD with age (Retz, Stieglitz, Corbisiero, Retz-Junginger, Rosler, 2012). However, cross-sectional studies on Adult ADHD have consistently shown a high prevalence of emotional dysregulation. Barkley, Murphy, and Fischer (2010) found 60% of adults with ADHD reported symptoms of deficient emotional self-regulation (DESR) from the Barkley Current Behavior Scale (Barkley, Fischer 2010) in a clinical sample. Likewise, Surman et al., (2011) found 54% of their subjects had prominent symptoms of DESR. Similar symptoms were seen in 72% of adults with ADHD in a study done on emotional dysregulation and

treatment with methylphenidate (Reimherr et al., 2010) and also in one third of adult ADHD patients in the treatment with atomoxetine (Reimherr et al., 2005).

Investigation of social problems related to emotional impulsivity in adult ADHD patients revealed impairment in occupational functioning, social interactions, education settings, criminal history, marital satisfaction, parenting stress, finances, driving, and leisure activities/recreational activities (Barkley, Murphy, 2009). The emotional impulsivity symptoms measured were impatient, quick to anger or upset, easily frustrated, over-react, easily excited, lose temper, and am touchy or easily annoyed, by the Emotional Impulsiveness Scale (EIS) (Barkley, 1997). EIS symptoms occurred in 53% to 86% of the ADHD group, which was nearly as frequent as symptoms of inattention (73%-97%), and more frequent than the symptoms of hyperactivity-impulsivity (30%-90%) (Barkley, Murphy, 2009). Emotional impulsivity is a severe symptom and common among adults with ADHD.

The clinical picture of ADHD can be quite complex. Inattention, hyperactivity-impulsivity are the current main symptoms of ADHD and provides an incomplete scope of this mental disorder. Evidence shows a tendency in adult ADHD to be more impulsive in your emotions. This can be seen as impatient, quick to anger, low frustration tolerance, easily annoyed, or displaying your emotions quicker than others. Symptoms of emotional dysregulation occur just as frequently as the core symptoms of ADHD, inattention and hyperactivity-impulsivity, and may cause impairments in social problems beyond the core symptoms. Reimherr et al., (2010) concluded that emotional dysregulation should be viewed as a distinct sub-group for adult ADHD. The prevalence of emotional symptoms in adult ADHD samples provide a strong argument to regard emotional impulsivity in ADHD psychopathology.

CHAPTER III

EXECUTIVE FUNCTION AND GO/NO-GO TASK

Adults with ADHD are shown to have deficits in executive functions (EFs), which Barkley (2012) defined "as those self-directed actions needed to choose goals and to create, enact, and sustain actions towards those goals, or more simply as self-regulation to achieve goals (p. 60)". Barkley (1997) proposed a hybrid model that divided the EFs into four domains: working memory, self-regulation of affect/motivation/arousal, internalization of speech, and reconstruction. Working memory includes holding events in mind, manipulating or acting on the events, imitation of complex behavior sequences, hindsight and forethought, a sense of time, and cross-temporal organization of behavior. Self-regulation of affect/motivation/arousal includes emotional self-control, objectivity/social perspective taking, self-regulation of drive and motivation, regulation of arousal in the service of goal-directed action. Internalization of speech involves describing or reflecting on an event, rule-governed behavior (instruction), problem-solving/self-questioning, generation of rues, and moral reasoning. Lastly, regulation includes analysis and synthesis of behavior, verbal/behavioral fluency, goal-directed behavioral creativity, and behavioral simulations, and syntax of behavior. Behavioral inhibition was conceptualized to be distinct from the EFs, however, a deficiency in inhibition results in difficulties in the EFs. Solanto (2014) notes that these difficulties result in reduced productivity, inefficiency, missed deadlines, poor planning, careless errors, and forgetting things as a result of disorganization. In some cases of ADHD, reduced inhibitory control may lead to emotional dysregulation and impairment in interpersonal interactions which may contribute to the failure to achieve goals personally, academically, and occupationally (Solanto, 2014). Research from Kessler et al.,

suggests that failure to achieve these goals may increase the likelihood of anxiety in adult ADHD.

Go/no-go task

The go/no-go paradigm has used extensively to test for behavioral inhibition with frontal lobe lesions in animals (Iverson, Mishkin 1970) and humans (Drewe, 1975; Leimkuhler, Mesulam, 1985). Results show that frontal lobe lesions cause trouble with inhibition in the task. Therefore, it is a common task used for demonstrating response inhibition and impulsivity, (Horn, Dolan, Elliott, Deakin, Woodruff, 2003; Eagle, Bari, Robbins 2008; Aichert et al., 2012) and more specifically in ADHD (Fenghua et al., 2016; Bezdjian, Baker, Lozano 2009). The go/no-go task requires participants to make a simple motor response such as a keypress to one cue (the go stimulus), while inhibiting this response in the presence of another cue (no go stimulus) (Trommer, Hoeppner, Zecker, 1991). Errors of commission are the most common and is the result of failing to inhibit a response when presented with the no go stimulus, which suggests impulsivity. On the other hand, errors of omission are the result of failing to respond when presented with the go stimulus, which advocates inattention. Adults with ADHD tend to commit more commission errors, omission errors, and have slower response times (Schulz et al., 2007; Bozorgpour, Klorman, Gift, 2013; Fisher, Aharon-Peretz, Pratt 2011; Wiersema, Meere, Antrop, Roeyers 2006).

Cursor motion

Measuring response time, commission errors, and omission errors are the main dependent variables in the go/no-go task. However, signs of fidgeting, hyperactivity, and emotion data cannot be seen through key presses. Cursor motion has been used in a variety of studies to find

correlations to emotion. Zimmermann (2008) analyzed cursor motion data in an online shopping task with emotion eliciting films and found that movement patterns differed greatly between the neutral and emotional mood state within individuals. Research indicates that cursor motion may predict people's anxiety levels when comparing area under the curve, path lengths, velocity, and spatial features (Yamauchi, 2013; Yamauchi, Seo, Choe, Bowman, Xiao 2015). To my understanding, no study is known where cursor motion is applied to the go/no-go task. However, Li et al., (2016) used infrared motion tracking from the Microsoft Kinect to measure movement intensity in children with ADHD across 15 frequency bands in the go/no-go task. They were able to distinguish between ADHD children and controls with significant correlations between some of the frequency bands and symptoms of inattention and hyperactive/impulsive on the ADHD rating scale.

Directed hand movement such as cursor motion can be seen as extensions to our body motions. This study aims to implement cursor motion in the go/no-go task to additionally measure the response time, total distance the cursor traveled, and acceleration. Participants with high potential for ADHD when measured with the CAARS questionnaire may have their emotional impulsiveness, hyperactivity, and anxiety be showcased in their cursor motion patterns. By analyzing the cursor motion trajectories, further understandings of ADHD in the go/no-go task can be gained.

CHAPTER IV

METHODS

Undergraduate students signed up for this study for course credit. Next, the participants were introduced to the go/no-go task which measured the capacity for sustained attention and response control. Then at a computer, students participated in a Conners Adult ADHD Rating Scale-Self-Report (CAARS; Conners, 1997) questionnaire that will score the participant's presence and severity of ADHD. We observed cursor trajectories to find a distinguishable pattern for potential ADHD in adults. All response collections were controlled by clicking the mouse, and all cursor motion activities (e.g., trajectory, clicking speed, velocity) were recorded. We applied data mining and machine learning algorithms to extract trajectory features that can predict individual differences pertaining to adult ADHD. Specifically, we compared the response speed, total distance, and acceleration between participants to find a correlation in participants with a high potential for ADHD versus low potential for ADHD.

Go/no-go task with keypress

The original keypress go/no-go task was programmed and ran with PsychoPy (Peirce, 2007). This task was similar to the go/no-go task used in (Gorman Bozorgpour, Klorman, & Gift, 2013) with some modifications. The go/no-go task consisted of 200 experimental trials, resulting in 100 (50%) go cues and 100 (50%) were no-go cues. Each trial began with a 250 ms fixation cross that always appeared at the center of the screen to direct your attention. This was immediately followed by either a go stimulus letter v, or a no-go stimulus number 2. The stimuli were presented in the center of the screen for 50 ms each. Participants

were instructed to press the spacebar when presented with the letter v, and to inhibit their response when presented with the number 2.

Before the task began, instructions were shown and 20 practice trials were administered. The task consisted of 200 experimental trials. Trials were presented every 2.5 s. No feedback was provided, nor was there an accuracy criterion before beginning the task (Gorman Bozorgpour et al., 2013)

Go/no-go task with cursor motion

The go/no-go task with cursor motion was programmed and ran with Opensesame (Mathôt, Schreij, & Theeuwes, J. (2012) The go/no-go task with cursor motion is nearly identical to the keypress go/no-go tasks, except the response mechanism involves cursor motion instead of keypresses. The cursor is reset to the bottom middle of the screen on stimulus presentation. On go responses, mouse movement to click on the box on the top middle of the screen is required. Cursor motion was measured using Mousetrap, which is an addon to the Opensesame program.

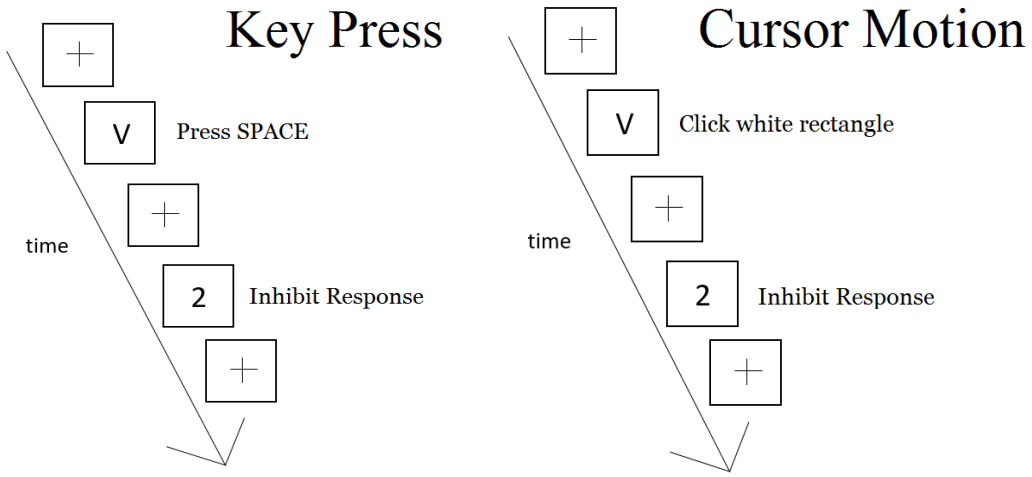

Fig 2. An example of trials in the go/no-go task. When the go cue (V) appears, participants were instructed to make a response. When the no go cue (2) appears, participants were instructed to inhibit their response.

CHAPTER V

RESULTS

We currently have a total of 110 participants, half (55) of the participants had the keypress task, and the other half (55) of the participants had the cursor motion task. We plan on running the experiment until we have 100 participants for the keypress task and 100 participants for the cursor motion task.

CHAPTER VI

DISCUSSION

The purpose of this study was to compare the cursor trajectory patterns in the go/no-go task of those who are vulnerable to ADHD and those who are not, and determine if the go/no-go task with cursor motion can match the ability to produce inhibition like the CAARS questionnaire. Reduced inhibitory control in adults with ADHD may lead to impairments in the executive function and emotional self-regulation. The go/no-go paradigm has been used extensively to test for behavioral inhibition by measuring the amount of errors resulting from the failure to inhibit your response when presented with a no go cue. Cursor motion has proved to be a good measure for detecting changes in emotion and anxiety (Zimmermann, 2008; Yamauchi, 2013; Yamauchi, Seo, Choe, Bowman, Xiao, 2015). Implementing cursor motion in the go/no-go task may reveal further insights on ADHD in adults.

Future Directions

In this study, we recruited Texas A&M undergraduates for course credit. We identified those who have high potential for ADHD and low potential for ADHD in participants by associating scores from the CAARS questionnaire. We compared cursor trajectory patterns such as response time, acceleration, and total distance. However, we did not measure the area under the curve like in many cursor motion experiments because our cursor motion response was a straight line. By implementing a choice-reaching task where participants have to choose between two similarly correct answers in the current go/no-go experiment will allow us to better measure the area under the curve (Fig. 3) (Yamauchi, 2013; Yamauchi, Seo, Choe, Bowman, Xiao, 2015).

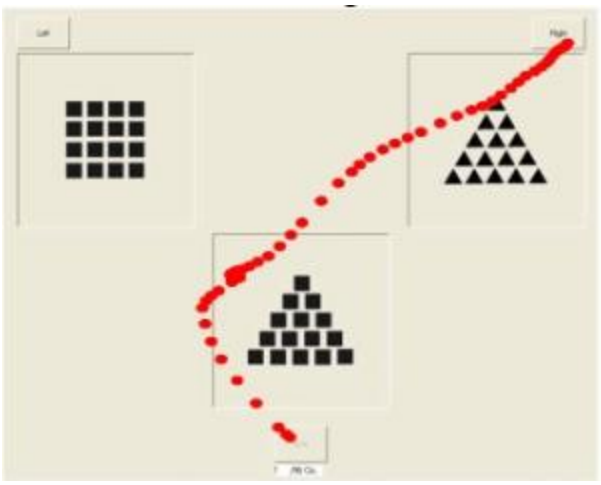

Fig. 3. Screenshot of choice-reaching task. Participants were to select if the top left or top right figure better matched the bottom figure. From: (Yamauchi, Seo, Choe, Bowman, Xiao, 2015).

Adding emotion eliciting stimuli in future go/no-go tasks may further differentiate potential ADHD adults. Cursor trajectories vary with emotion eliciting stimuli, and adult ADHD patients are susceptible to emotional impulsivity. Analyzing cursor trajectory data with emotion eliciting stimuli as seen in Yamauchi and Xiao (2016) may be another promising line of research.

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