

SMART: A PILOT VALIDATION STUDY OF A
NEW TEST OF ATTENTION

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By

KAREN BRODIE

ABSTRACT

Attention Deficit Hyperactivity Disorder (ADHD) is one of the most prevalent externalizing disorders that can cause impairments in attention and concentration. It can impact many aspects of an individual's educational, social, and emotional adjustment. As it is important to accurately diagnose whether an individual has ADHD, it is essential to use a measure that reduces as much technical error as possible. The purpose of this study was to test the validity of a new electronic measure of attention (the The Stewart Machine for Attention Response Timing (SMART)) which does not rely on a separate computer or operating system to present stimuli or collect results.

Undergraduate participants from the University of Saskatchewan and Concordia University College of Alberta were asked to complete the SMART, the Brief Test of Attention, and fill out a short questionnaire based on the DSM-IV-TR, regarding attention behaviours and past diagnosis. Psychometric properties of the SMART were examined and showed no significant differences between the participant groups (by province) except on the number of participants with prior diagnosis of attention difficulties (with a greater number of Saskatchewan participants with prior diagnosis). There was not a significant difference between the SMART trial one and trial two except on the response time variable, indicating that the distracter story included in trial two did not make a significant difference on performance. Inspection of the four time quadrants revealed internal consistency on all measures except for the response time variable, in which the fourth time quadrant in which response time was significantly quicker. Exploration of the concurrent validity between the BTA and the SMART revealed significant correlations between the BTA and the response time, response time variability and total error scores, with the strongest relationship with the total error score. The SMART trial two total error

score showed utility in identifying individuals who have attention difficulties as identified by the BTA. It is hoped that this study will make a significant contribution to the assessment of ADHD, the accuracy of diagnosis, and the utility of technologically-based measures.

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CHAPTER 1

INTRODUCTION

In North America, individuals who display inattentive and impulsive behaviours often experience great difficulties in their social, academic, and emotional development. When the behaviours are significant and long standing (i.e., since childhood), an individual may be diagnosed with Attention Deficit Hyperactivity Disorder (ADHD), as defined by the Diagnostic and Statistical Manual of Mental Disorders – Fourth Edition – Text Revision (DSM-IV-TR). The DSM-IV-TR has identified criteria for the diagnosis of ADHD, which is divided into the Inattentive, Hyperactive-Impulsivity, combined and not otherwise specified, subtypes (American Psychiatric Association [APA], 1994). Six or more maladaptive symptoms of inattention or hyperactivity must be present and have persisted for at least six months. Individuals with ADHD are often associated with having “attention deficits (distractibility), hyperactivity (fidgetiness), impulsivity, mood swings, short temper, high sensitivity to stress, and an impaired ability to make and follow plans” (Kalat, 2004, p. 221). Significant impairment from these symptoms must be present in two or more settings (i.e., school or work and at home) and clear evidence of the impairment in social, academic, or occupational functioning is required (APA, 1994).

The evidence of attention problems and impairment is typically gathered through a variety of assessment procedures. One of the common diagnostic tools used in assessment of ADHD is questionnaires. Self or informant reports are used to explore an individual’s current and/or past behaviours. Many questionnaires explore the severity and frequency of the behaviours associated with ADHD. As symptoms of ADHD must be present before the age of 7, questionnaires enable the clinician to gain information about the individual’s behaviours as a

child and compare them to the present (Barkely, 2000; Katz, Petscher, & Welles, 2009; Mannuzza, Klein, Klein, Bessler, & Shrouf, 2002; Murphy & Adler, 2004). It is important to gain an understanding of long standing difficulties an individual has experienced, as well as obtaining accurate information regarding an individual's current attention and concentration abilities. Objective and standardized measurement tools are used alongside questionnaires to examine inhibition and inattention in a controlled setting.

The structured measures examine an individual's attention and concentration levels on a specific task by comparing their performance to a normative sample. Standardized measures explore different aspects of attention and concentration (i.e., impulsivity, interference control, sustained and selective attention, etc.) through paper-and-pencil, auditory listening tasks, and computerized continuous performance tests. Common paper-and-pencil tests, such as the Stroop Colour Word Test and the Ruff 2 and 7 test, measure executive functioning, interference control and impulsivity (Fischer, Barkley, Smallish, & Fletcher, 2005; Knight, McMahon, Skeaff, & Green, 2010; Messinis, Kosmidis, Tsakona, Georgiou, Aretouli, & Papathanasopoulos, 2007; Pocklington & Mayberry, 2006; Van der Elst, Van Boxtel, Van Breukelen, & Jolles, 2006). Auditory listening tasks, like the Brief Test of Attention and the Auditory Process Training Test – II, examine selective, sustained, divided, and alternating attention (Cooley & Morris, 1990; Murray, Keeton, & Karcher, 2006; Park, Proulx, & Towers, 1999; Schretlen, Bobholz, & Brandt, 1996; Schretlen, Brandt, & Bobholz, 1996; Youse & Coelho, 2009). Computerized tests use technology to measure impulsivity, inattention, and processing speed. Tests, such as the Conners Continuous Performance Test – Second Edition (CPT-II) and the Test of Variables of Attention (TOVA), measure these constructs by recording correct and incorrect responses, and documenting response rates in milliseconds. The means and standard deviations of the variables

are compared to a normative group and used to determine whether difficulties are present (Cernich, Brennana, Barker, & Bleiberg, 2007; Häusler, Sommer, & Chroust, 2007; Klecker, 2004; Květon, Jelínek, Vobořil, & Klimusová, 2007; Loew, 2004; Whiston & Kane, 2004). Structured measures and questionnaires identify attention problems and can lead to a diagnosis of ADHD.

Context of Research

As noted above, the presence of ADHD can have a significant impact in an individual's social and emotional well being. Adults with ADHD are reported to “have more occupational, family, emotional and interpersonal problems” (Passer, Smith, Atkinson, Mitchel, & Muir, 2005, p.568) and diagnosis can aid in understanding for the individual, as they are dealing with their current life situations, and for others, who are impacted by the individual's behaviours. Diagnosis is also important for developing strategies to enhance an individual's attention and concentration levels, thus lowering the frustration that commonly accompanies these problems and increasing the quality of life.

It is important for diagnosis to be accurate, as it can affect the strategies and treatment employed in the management of ADHD. While the current tools used in the diagnosis of ADHD provide essential information, it is noted that all measures have specific inherent problems that impact their efficacy (Adler, Faraone, Spencer, Michelson, Reimherr, Glatt, Marchant, & Biederman, 2008; Barkely, 2000; Kooij, Boonstra, Swinkels, Bekker, de Noord, & Buitelaar, 2008; Květon et al., 2007; Van Mourik, Oosterlaan, & Seargent, 2005; Zucker, Morris, Ingram, Morris, & Bakeman, 2002). Subjective measures, such as questionnaires, are prone to discrepancies in the presence and severity of perceived behaviour between self and informant-reports and between inattentive and hyperactive behaviours (Adler et al., 2008; Barkely, 2000;

Katz et al., 2009; Kooij et al., 2008; Mannuzza et al., 2002; Murphy & Adler, 2004; Perugini et al., 2000; Ward, Wender, & Reinherr, 1993; Wender 1995; Van Mourik et al., 2005; Zucker et al., 2002). Objective measures, such as paper-and-pencil and auditory tests, allow an examiner to compare the individual's results to a normative group. These tests explore sustained, divided, and selective attention, and overall executive functioning. The full effects of timing, other skills (i.e., mathematical abilities, memorization skills), and practice from repeated exposure on these tests is unknown, as such, their efficacy as stand-alone attention tests is suspect and must be completed along-side other measures (Lemay et al., 2004; Murray et al., 2006; Park et al., 1999). Computerized attention tests measure impulsivity and attention through the recording of timed responses. Accurate timing is crucial in these measures as the responses are recorded in milliseconds. Studies have shown potential sources of timing error that significantly impact an individual's reported performance: number of programs running in the back ground, the operating system, amount of RAM, signal speed from peripheral instruments, and the interaction between the hardware and software (Cernich et al., 2007; Häusler et al., 2007; Květon et al., 2007). Technical error can significantly alter an individual's reported performance, and thus, can impact the diagnosis of ADHD.

Purpose of the Study

As it is important to accurately diagnose whether an individual has ADHD, for educational, academic, social and emotional well being, it is essential to use a measure that reduces as much technical error as possible. The purpose of this study was to test the validity of a new electronic measure of attention (the The Stewart Machine for Attention Response Timing (SMART)) that does not rely on a separate computer or operating system to present stimuli or collect results. The SMART is an instrument created by Dr. Garth Stewart to examine attention

and processing speed, over two test conditions. This is a pilot project which began exploring the psychometric characteristics of the SMART. The psychometric properties of the SMART were examined by comparing participant results on the SMART with a currently used attention test (the Brief Test of Attention) and short questionnaire regarding attention behaviours and past diagnosis. This study has a strong diagnostic emphasis with the potential to make a significant contribution to the assessment of ADHD, the accuracy of diagnosis, and the utility of technologically-based measures.

CHAPTER 2

ATTENTION DEFICIT HYPERACTIVITY DISORDER

Attention Deficit Hyperactivity Disorder (ADHD) is one of the most common of the externalizing disorders that can cause impairments in attention and concentration. This disorder is known to be quite prevalent and has multiple and serious impacts on many aspects of the individual's educational, social, and emotional adjustment. A biological basis for ADHD has been identified and implicates many areas of the brain that are directly involved in attention and concentration. Kalat (2004) notes ADHD "is characterized by attention deficits (distractibility), hyperactivity (fidgetiness), impulsivity, mood swings, short temper, high sensitivity to stress, and impaired ability to make and follow plans" (p. 221).

Historical Background

ADHD behaviours have been documented throughout history. Some of the earliest reports of these behaviours are noted from ancient Greece (Brassett-Harknet & Buttler, 2007). Historically these behaviours were thought to stem from brain damage and this was the prevalent belief until the 1960s. Culbertson and Krull (1996) note "in the early twentieth century, descriptions of hyperactivity, inattention, and poor impulse control appeared in medical literature as sequelae of head injuries, encephalitis or various central nervous system infections" (p.271). Children with these behaviours were described by researcher G.F. Still (1902) as aggressive, defiant, displaying lawlessness, having little inhibitory volition, and have "a major deficit in moral control" (p.1009). Still's definition of the behaviour was the first formal description of what we now know as ADHD (Brassett-Harknet & Buttler, 2007). Still attributed much of the behaviour to brain disease and that the behaviours could be remedied upon recovery (Culbertson

& Krull, 1996). Many of the behaviours observed were similar to those of children who had incurred a brain injury even though they themselves had not undergone such an experience and they were therefore characterized as having brain damage syndrome (Barkley, 1990). Children with brain damage syndrome presented many learning and behavioural deficits, such as impulsivity, hyperactivity, and distractibility (Culbertson & Krull, 1996). During the 1960's an emphasis on behavioural attributes of the disorder lead to the altering of the diagnosis to Hyperactive Child Syndrome which is reflected in the term Hyperkinetic Reaction of Childhood listed in the Diagnostic and Statistical Manual of Mental Disorders (DSM-II; American Psychiatric Association, 1968). Phillips (2002) notes an important historical aspect of this disorder was the inclusion of inattention and distractibility in the diagnostic criteria. In 1980, the DSM-III incorporated new findings from research to the diagnosis and renamed the disorder Attention Deficit Disorder. Under this new title, the emphasis was primarily placed on difficulties with attention, and the behavioural symptoms of impulsivity and hyperactivity were viewed as secondary issues (Culbertson & Krull, 1996; Phillips, 2002). After substantial research, Virginia Douglas developed a fourfold theory of ADD symptoms: a) deficits in attention and effort, b) difficulties inhibiting impulsive responses, c) trouble modulating arousal, and d) immediate reinforcement seeking behaviours (Culbertson & Krull, 1996; Phillips, 2002). Such studies have lead to the inclusion of subtypes that are seen in the DSM-IV-TR.

Criteria for ADHD Diagnosis

The Diagnostic and Statistical Manual of Mental Disorders (DSM-IV-TR) has identified criteria for the diagnosis of ADHD, which is divided into the Inattentive, Hyperactive-Impulsivity, combined and not otherwise specified subtypes (American Psychiatric Association, 1994). Children with ADHD- Inattentive subtype are likely to have difficulties in school,

experience trouble following instructions, and often appear not to listen. Throughout their lifetime, individual's with ADHD- Inattentive subtype struggle with many aspects of learning and fail to pay close attention to details or make careless mistakes. These children are distracted by extraneous stimuli, have difficulty sustaining attention, show difficulty organizing tasks or activities, lose things necessary for tasks, and/or avoid activities requiring sustained mental effort (Culbertson & Krull, 1996; Kalat, 2004; La Malfa, Lassi, Bertelli, Pallanti, & Albertini, 2008; Nietzel, Speltz, McCauley, & Bernstein, 1998). Children with ADHD- Hyperactive-Impulsive subtype also have marked difficulties in the academic setting as they blurt out answers before questions are completed, interrupt conversations, and have difficulty awaiting their turn. They often have difficulty staying in their seat and show excessive amounts of activity, which may present in older individuals as feelings of restlessness (Culbertson & Krull, 1996; Kalat, 2004; La Malfa et al., 2008; Nietzel et al., 1998). For a diagnosis of ADHD the symptoms must have a pervasive global negative effect on their lives and be present for a minimum of six months.

ADHD is defined in the DSM-IV-TR as follows:

A. Either 1 or 2:

1. Six or more of the following symptoms of **inattention** have persisted for at least six months to a degree that is maladaptive and inconsistent with

developmental level:

- a.** Often fails to give close attention to details or makes careless mistakes in schoolwork, work, or other activities.
- b.** Often has difficulty sustaining attention in tasks or play activities.
- c.** Often does not seem to listen when spoken to directly.

- d.** Often does not follow through on instructions and fails to finish schoolwork, chores, or duties in the workplace (not due to oppositional behavior or failure to understand instructions).
- e.** Often has difficulty organizing tasks and activities.
- f.** Often avoids, dislikes, or is reluctant to engage in tasks that require sustained mental effort (such as homework).
- g.** Often loses things necessary for tasks or activities (toys, school assignments, pencils, books, or tools).
- h.** Is often easily distracted by extraneous stimuli.
- i.** Is often forgetful in daily activities.

2. Six or more of the following symptoms of **hyperactivity–impulsivity** have persisted for at least six months to a degree that is maladaptive and inconsistent with developmental level:

Hyperactivity

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

Impulsivity

- g.** Often blurts out answers before questions have been completed.
 - h.** Often has difficulty awaiting turn.
 - i.** Often interrupts or intrudes on others (such as butting into conversations or games).
- B.** Some hyperactive, impulsive, or inattentive symptoms that caused impairment were present before age seven.
- C.** Some impairment from the symptoms is present in two or more settings (such as in school or work and at home).
- D.** There must be clear evidence of clinically significant impairment in social, academic, or occupational functioning.
- E.** The symptoms do not occur exclusively during the course of a pervasive developmental disorder, schizophrenia, or another psychotic disorder and are not better accounted for by another mental disorder such as a mood, anxiety, dissociative, or personality disorder.

AD/HD Types Using DSM-IV criteria

AD/HD, predominantly inattentive type - Meets inattention criteria (section A1) for the past six months.

AD/HD, predominantly hyperactive-impulsive type - Meets hyperactive-impulsive criteria (section A2) for the past six months.

AD/HD, combined type - Meets criteria for section A1 and section A2 for the past six months.

AD/HD, not otherwise specified – Prominent symptoms of inattention or hyperactivity–impulsivity that do not meet the criteria for AD/HD.

In partial remission.

The new edition of the DSM (DSM-5) is proposed to contain different criteria for ADHD diagnosis. These changes include: the symptoms be present before the age of 12, a change of three subtypes to four current presentations (with the addition of a fourth presentation of restrictive inattentive), requirement that informant information come from two sources instead of one, and a review of the number of symptoms required for ADHD to be diagnosed in adults (Coghill & Seth, 2011; DSM Development, 2012; Ghanizadeh, 2012). Four new symptoms have also been proposed to be included in the criteria: “Tends to act without thinking, such as starting tasks without adequate preparation or avoiding reading or listening to instructions, may speak out without considering consequences or make important decisions on the spur of the moment, such as impulsively buying items, suddenly quitting a job, or breaking up with a friend”, “Is often impatient, as shown by feeling restless when waiting for others and wanting to move faster than others, wanting people to get to the point, speeding while driving, and cutting into traffic to go faster than others”, “Is uncomfortable doing things slowly and systematically and often rushes through activities or tasks”, and “Finds it difficult to resist temptations or opportunities, even if it means taking risks (A child may grab toys off a store shelf or play with dangerous objects; adults may commit to a relationship after only a brief acquaintance or take a job or enter into a business arrangement without doing due diligence)” (DMS Development, 2012; Ghanizadeh, 2012). Coghill and Seth (2011) note that the changes include an emphasis on ADHD

being a disorder of both behavioural and cognitive functioning, recognizing the organic nature of ADHD. Research conducted by Lahey and Willcutt (2010) and Ghanizadeh (2012) supports classifying ADHD with current presentations instead of subtypes, as individuals with ADHD often display diverse symptoms at different stages in their lives. The wording on some of the criteria examples is also proposed to be changed and will include examples that are more consistent with adult presentation (Coghill & Seth, 2011; DSM Development, 2012). The DSM criteria are an inclusive guideline for diagnosis and treatment of ADHD for both children and adults.

Biological and Environmental Factors

Genetic and Biological Factors

Genetic/biological and environmental factors each play a part in the etiology of ADHD. “Family studies have identified a 2- to 8-fold increase in the risk for ADHD in parents and siblings of children with ADHD. Various twin and adoption studies have also highlighted the highly genetic nature of ADHD” (Furman, 2008, p. 775). Recent twin studies continue to corroborate the biological basis for ADHD (Kieling, Goncalves, Tannock, & Castellanos, 2008; Pearsall-Jones, Pieka, Martina, Rigolia, Levyc, & Haya, 2008). The brain has many areas that are involved in attention, including, but not exclusive to, the corpus callosum, midbrain structures, and the frontal lobes, specifically the prefrontal cortex (Culbertson & Krull, 1996; Overmeyer et al., 2000; Silk, Vance, Rinehart, Bradshaw, & Cunnington, 2008; Steger et al., 2001). Barkley and Murphy (2006) summarize the neurobiological factors involved in ADHD:

The central psychological deficits in those with ADHD have now been linked through numerous studies using various scientific methods to several specific brain regions (the frontal lobe, its connections to the basal ganglia, and their relationship to the central

aspects of the cerebellum). Most neurological studies find that as a group those with ADHD have less brain electrical activity and show less reactivity to stimulation in one or more of these regions. And neuro-imaging studies of groups of those with ADHD also demonstrate relatively smaller areas of brain matter and less metabolic activity of this brain matter than is the case in control groups used in these studies. (p. 54)

The recent body of literature also implicates the striatum and the cerebellar vermis in the biological make up of ADHD (Cao et al., 2009; Durston et al., 2008; Mackie et al., 2007; Silk et al., 2008; Swanson & Volkow, 2009). Mackie and colleagues (2007) report on the multiple functions of the cerebellum that are often impaired in individuals with ADHD, including temporal attention processing, implicit learning, verbal working memory, emotional regulation, executive functioning, and shifting attention. Cao and colleagues (2009) indicate the role of the striatum in working memory, executive functioning and language processing. Although both structures are rich in dopamine transporters, individuals with ADHD typically experience under-activation that result in impairments (Cao et al., 2009; Durston et al., 2008; Mackie et al., 2007; Silk et al., 2008; Suskauer et al., 2008; Swanson & Volkow, 2009) . Each of the above mentioned areas has a highly specialized function in attention and as a result, dysfunction in any area can lead to varying deficits in an individual's attention and concentration abilities.

Environmental Factors

Furman (2008) explores other factors that impact ADHD: “food additives/diet, lead contamination, cigarette and alcohol exposure, maternal smoking during pregnancy, and low birth weight” (p.775). It is noted that low socioeconomic status, poor health care and environmental instability also contribute to the development, or at least exacerbate the severity, of ADHD (Culbertson & Krull, 1996; Nietzel et al., 1998). An interaction effect between the

environmental factors and a genetic predisposition is possible and must be taken into consideration during assessment. With the knowledge that environmental factors can greatly influence the development and function of the brain, it is important to consider all aspects of a person's life when conducting assessment to determine whether they have ADHD.

Prevalence of ADHD

According to Human Resources and Social Development Canada (HRSCD), the best estimate for the prevalence of ADHD in children ranges from 5-10% (HRSCD, 2.1, n.d.). However, Dr. Andrew Roland and colleagues report that this may be an underestimate of the actual pervasiveness of ADHD and noted in their 2001 study, in which they tested children who had not been specifically identified as having ADHD, that “39% of the cases [of the total number of children who presented with attention problems] had not been previously diagnosed” (Rowland et al., 2001, p.939) with ADHD. Approximately 50- 80% of children who are diagnosed with ADHD continue to have difficulties throughout adolescence and 30- 50% present significant symptoms into adulthood (Passer et al., 2005; Schweiger, Abramovitch, Doniger, & Simon, 2007). Passer and colleagues (2005) report “overall, adults with ADHD have more occupational, family, emotional and interpersonal problems” (p.568). It is evident that the social/emotional impact of ADHD is highly significant, regardless of whether the disorder is formally diagnosed or not.

Diagnosis of ADHD

Questionnaires

Diagnosis of ADHD is important as it can lead to treatments and strategies that improve an individual's attention and concentration levels, thus lowering the frustration that often

accompanies these problems and increasing the quality of life. Questionnaires are diagnostic tools commonly used in the assessment of ADHD. Self or informant accounts are used to report on an individual's current and/or past behaviours. Questionnaires are used to explore the severity, frequency, and duration of behaviours associated with ADHD. Adults are asked to take a retrospective look at their behaviours as a child, or have another person report on their past behaviours in order to meet the DSM-IV criteria of having symptoms present before the age of seven (Barkely, 2000, Collett, Cowley, Gimpel, & Greenson, 2000; Katz, Petscher, & Welles, 2009; Mannuzza et al., 2002; Murphy & Adler, 2004; Murphy & Scharcar, 2000; Ward et al., 1993).

While it is important to gain information about an individual's behaviours, the literature points out it can be problematic to gain an accurate portrayal of the individual's behaviours, either past or present. Research indicates that adults have difficulty commenting on their past as they may have a distorted or inaccurate recall of their behaviours, not recognizing their behaviours as problematic or reporting their behaviours as more severe than their parents or observers indicate (Adler et al., 2008; Barkely, 2000; Katz, Petscher, & Welles, 2009; Kooij et al., 2008; Mannuzza et al., 2002; Murphy & Adler, 2004; Murphy & Schacar, 2000; Ward et al., 1993; Wender, 1995; Zucker et al., 2002).

There are inconsistencies in the current body of literature regarding the discrepancies found between informant and self-report accounts on the severity of hyperactive and inattentive behaviours. Many studies have not found discrepancies between current and retrospective self-reports for both inattentive and hyperactive behaviours; as well, Zucker and colleagues (2002) noted that rated levels of hyper-activity and impulsivity were generally concordant between self and informant reports (Kooij et al., 2008; Smith et al., 2000; Zucker et al., 2002). Conversely,

there have been differences found between self and informant reports measuring inattentive behaviours: inattention issues are rated by informants as more significant than by the individual, especially if the informant is a parent (Kooij et al., 2008; Smith et al., 2000; Zucker et al., 2002). In contrast, other studies found a marked difference between self and informant reports, in which the informant consistently reported less severe symptomology in all aspects than the individual (Adler et al., 2008; Katz, Petscher, & Welles, 2009). Although there are not congruous findings regarding informant reports, the literature consistently indicates that it is common for individuals with ADHD to have difficulty identifying and reporting internal aspects of ADHD, such as inattention, and impulsivity to a lesser degree, but are adept at reporting external behaviours, such as hyperactivity, and the negative social impact (Adler et al., 2008; Katz, Petscher, & Welles, 2009; Kooij et al., 2008; Smith, Pelham, Gnagy, Molina, & Evans, 2000; Zucker et al., 2002). Questionnaires remain an invaluable source of information regarding an individual's behaviour, but should be used in combination with less subjective measures for an accurate ADHD diagnosis.

Objective Measures

Due to the subjective characteristics of questionnaires, ADHD assessments will often incorporate objective, structured tasks to measure an individual's attention and concentration. These measures examine an individual's performance on specific attention and inhibition tasks, by comparing the performance to a normative sample. An inference is made, in conjunction with information gleaned from questionnaires, regarding whether the individual qualifies for an ADHD diagnosis. Some of the most frequently used measurement tools of this type are paper-and-pencil tools (i.e., the Stroop Colour Word Test (STROOP) and the Ruff 2 and 7 Selective Attention Test (2 and 7 test)), measures that use audio technology (i.e., the Brief Test of

Attention and the Attention Process Training Test), as well as computerized tests (i.e., the Conners' Continuous Performance Test – second edition (CPT-II) and the Test of Variables of Attention (TOVA)).

Paper-and-Pencil Tests.

The Stroop Colour Word Test (STROOP) is used for measuring impulsivity and interference control (Quinn, 2004; Van der Elst et al., 2006). It is a tool that measures an individual's performance on a basic task and compares it to an analogous task in which the usual response must be inhibited for a less-automatic response (Homach & Riccio, 2004; Perugini et al., 2000; Pocklington & Mayberry, 2006; Van der Elst et al., 2006; Van Mouric et al., 2005). The STROOP has shown to be an efficient tool to measure interference control and executive functioning, constructs in which individuals with ADHD have marked difficulties (Homach & Riccio, 2004; Pocklington & Mayberry, 2006; Van der Elst et al., 2006; Van Mouric et al., 2005), however, Van Mouric and colleagues (2004) and Perugini and colleagues (2000) note that it should not be used alone in assessment of ADHD. The STROOP's validity in diagnosis of ADHD, as with all measures, increases when it is used in conjunction with other assessment measures (Perugini et al., 2000; Van Mourik et al., 2005).

The Ruff 2 and 7 Selective Attention Test (2 and 7 test) (Ruff & Allen, 1996; Ruff, Evans, & Light, 1986) is a paper-and-pencil measure also used in the diagnosis of ADHD. It is a cancellation task in which the individual must detect all of the 2s and 7s in two different test conditions. The initial condition consists of the numbers 2 and 7 being embedded amongst letters and the second condition is comprised of all numbers. Knight and colleagues (2010) and Messinis and colleagues (2007) note that the detection of the numbers in first condition is considered to be an automatic process, as the stimuli are from different categories, whereas the

second condition requires more selective attention and a controlled search process to discriminate the target numbers from the distraction numbers. Messinis and colleagues report the 2 and 7 test “is based on the premise that selective attention (i.e., the ability to select relevant stimuli while ignoring irrelevant information) can be assessed by comparing automatic detection versus controlled processing with minimal demands on other cognitive processes such as internal processing of information or immediate memory” (2007, p. 774). The 2 and 7 test has shown to be an effective tool to differentiate individuals with attention and executive functioning problems from those without across a variety of populations and age ranges (Fischer et al., 2005; Knight et al., 2010; Lemay et al., 2004; Messinis et al., 2007). Lemay and colleagues (2004) note that the 2 and 7 test has good psychometric properties and can be used in subsequent assessments, however, due to practice effects, longitudinal interpretations should not be made.

Auditory tests.

The Brief Test of Attention (BTA) is an auditory test of selective attention. Selective attention consists of the ability to attend to a specific aspect of stimuli while disregarding other aspects. It has been designed to be used with nonaphasic (the ability to speak or understand spoken language) individuals and was developed to generate a simple test of sustained and selective attention based on Cooley and Morris’ (1990) model of sustained and divided attention (Schretlen et al., 1996). Sustained attention is maintaining attention over a prolonged amount of time. Divided attention is the ability to attend to two or more actions at the same time. This model depicts four levels of processing that influence the inhibition and attending factors. Tonic arousal is the most basic level, modality-linked sensory registration processes define the second level, modality-specific perceptual processes is the third, and the fourth is comprised of conceptual processing (Cooley & Morris, 1990). Cooley and Morris postulated that each of the

four levels correspond to the verbal, spatial, memory, motor and executive functioning neuropsychological systems. The current body of literature suggests that the BTA is a strong measure of attention with a variety of populations (Cooley & Morris, 1990; Des Rosiers, & Kavanagh, 1978; Schretlen et al., 1996a; Schretlen et al., 1996b; Snow et al., 1988).

The Attention Process Training Test – II (APT-II) is an auditory measure of selective, sustained, divided and alternating (the mental flexibility to move between tasks with different cognitive requirements) attention. It assesses attention across these four domains and was designed as a rehabilitation tool for individuals with mild cognitive dysfunction in order to increase attentional abilities. The APT-II places increasing demands on attention control through the use of timing, repetition and manipulation of auditory information (Boman et al., 2004; Murray et al., 2006; Palmese & Raskin, 2000; Park et al., 1999; Sohlberg, Johnson, Paule, Raskin, & Mateer, 1994; Sohlberg & Mateer, 1986; Sohlberg & Mateer, 2001; Youse & Coelho, 2009). While the APT-II was intended to be utilized with individuals who have attention and concentration difficulties as a sequelae of an acquired brain injury, it has also been effective as a measurement tool that can be used to assess attention regardless of the presence of brain injury. In their 2009 study, Youse and Coelho reported that the efficacy of the APT-II as an assessment tool surpassed its use as a training tool. While the APT-II is marketed as a tool to increase attention, it is noted that improvement observed may actually be a result of an increase in mental arithmetic and memorization skills and not necessarily an increase in attentional abilities (Murray et al., 2006; Park et al., 1999). These findings call into question the full impact of poor mathematical skills and memorization abilities on an individual's performance on APT-II. There are currently no studies that explore whether poor arithmetic and memorization skills negatively affect an individual's attention score.

Computer tests.

While the paper-and-pencil and auditory measures tap into different aspects of attention, it is difficult to accurately measure timing and latency of an individual's responses when exploring the inattention and impulsivity aspects of ADHD with untimed paper and pencil tasks. As such, computers have become a vital part of psychological assessment and are frequently utilized in the diagnosis of attention problems. This type of technology is beneficial to the process of assessment as it includes measurement of reaction times, stricter standardization of testing procedures, faster and more consistent scoring, and built in storage of test results (Cernich et al., 2007; Häusler et al., 2007; Květon et al., 2007). Because of advantages like these, the Test of Variables of Attention (TOVA) and the Conners Continuous Performance Test – Second Edition (CPT-II) computerized tests of attention have become widely used. Both tests examine the amount of time required to correctly respond to the stimuli and the standard deviations of the variability in response times to help determine whether the participant has difficulties with processing speed and/or deficits in sustained attention. Professors Susan Whiston and Harrison Kane (2004) note the response time variability is thought to be the most crucial measure on the TOVA as it analyzes the participant's performance over a sustained amount of time. The stimuli are presented for 100 milliseconds every 2 seconds and the response times are recorded through pressing a micro switch (Loew, 2004). The CPT-II also measures response time variability across the test, as well as examining the participant's reaction speed to different presentation rates and the standard error of these scores (MMY, 2004). The CPT-II presents the stimuli for 250 milliseconds at varying intervals of 1, 2, and 4 seconds and classifies response times of less than 100 milliseconds as a perseveration of the previous stimulus (Klecker, 2003). As timing on these tests is measured in tiny increments, computers are used to administer and record the

responses, and to compute different statistical analysis.

Timing accuracy.

While there are many benefits to using computerized assessment tools, there are many technological concerns that could potentially invalidate the results gained from such administrations. As the timing is highly sensitive, it is crucial to identify possible obstructions that could interfere with accurate assessment recording. Häusler, Sommer and Chroust (2007) report “inter-individual variance in the measured reaction times are usually small in the sense that the central 50 percent of a norm population range within less than 100ms. Technical measurement errors therefore have the potential to seriously affect the validity of diagnostic judgments based on such measures” (p.116). Various aspects of a computer, including differences in operating systems (OS) and peripheral devices for signaling a response could significantly increase timing error and must be taken into consideration when utilizing measures, such as the CPT-II and the TOVA, that emphasize response time variables for diagnostic purposes. Studies have shown detectable errors of measurement that have impacted the results up to 20 percentile ranks due to hardware and software interaction (Cernich et al., 2007; Häusler et al., 2007; Květon et al., 2007).

The OS is essential to the use of a computer and can significantly impact the accuracy of computerized assessment tools. The speed and delay in between a reported display rate and actual display rate can vary depending on the system being used. Older programs, such as Windows 95 and 98, have up to 55ms of delay, whereas newer programs, like Windows XP, show 10 - 15ms of delay between reported and actual display times (Cernich et al., 2007). These delays are caused by the amount of time required to process the command of a program, retrieving data from the graphics card and then presenting the information on the screen (Häusler

et al., 2007; Květon et al., 2007). Automatic programs run by the OS in the background (i.e., anti-virus programs, computer updates, retrieving and saving information, etc.) also effect the discrepancy between reported and actual display rate, as the OS momentarily suspends action in one program to attend to another (Cernich et al., 2007; Ghosh & Rajkumar, 2002; Häusler et al., 2007; Květon et al., 2007). Cernich and colleagues note “if multiple programs are running alongside the testing software, and this has not been addressed by the software itself, additional and unpredictable error will be introduced” (2007, p.542). These errors can substantially affect timing for programs that measure response rate in milliseconds as the participant is not exposed to the stimuli at the time recorded, thus creating a larger lag between recorded presentation and response.

Another area of concern is the technology used to display the stimuli. The display on a computer monitor is typically presented in a pixel-by-pixel method that starts in the top left hand corner and scrolls row by row to the bottom right of the screen. The time it takes for the computer to complete this process is called the refresh rate, which lasts between 10 – 18 ms (Cernich et al., 2007). Concern has been raised regarding the timing of the refresh cycle and intended display time of a stimuli, therefore if the two do not coincide, the stimuli will be seen either earlier or later than intended and cause further timing difficulties (Cernich et al., 2007; Häusler et al., 2007; Květon et al., 2007). Both the TOVA and the CPT-II utilize a computer screen to present the stimuli and record the latency between presentation and response.

Computer-based assessment measures use peripheral instruments to obtain the participant’s response such as a keyboard, mouse or micro switch. The computer’s processor detects changes in the current flowing through the circuit from the instrument, an indication that a key has been pressed, and sends the information to the OS, which forwards it to the appropriate

location. The computer's processor samples the information coming from the peripheral instruments and responds when it is different (Cernich et al., 2007; Ghosh & Rajkumar, 2002; Häusler et al., 2007). The rate at which the instruments are sampled vary between processors and OS's leading to a discrepancy of response times from when the response was actually made to when the computer detected it. As well, the technology used in these tools can greatly affect the timing recorded. Plant, Hammond and Whitehouse (2003) noted a significant impact on time measurement when they examined the effect of using different mice on the same program and computer. The physical properties of the peripheral devices can also influence response timing, for example, the force required to press the button or keyboard key, the configuration of the device, and/or the size of the button can affect performance, and as a result, impact the timing and eventual diagnosis of attention problems (Cernich et al., 2007; Häusler et al., 2007). The creators of the TOVA have addressed this issue by including "a specially designed highly accurate (+/- 1 msec) electronic micro switch" (Loew, 2004, para. 2) so that all administrations of the TOVA are subject to the same electronic device. However, this does not take into consideration the disparity between processors and OS. The CPT-II relies on the computer and peripheral instruments to record responses and as noted, this can markedly affect the reaction time scores.

Research has identified possible resolutions to minimize computer error with computer-based assessments; however, there are none that completely eradicate the problems. Some solutions offered include preventing multiple programs from running during the testing session, calibrating the OS internal time with the testing program, and indicating the minimal requirements of peripheral devices compatible with the program. Issues that have not been investigated involve the amount of RAM available and the processor speed, both of which could

affect the speed at which the program itself runs.

The current computer-based assessment tools available are inundated with potential technologically based errors that could significantly affect the validity of the tests. Häusler and colleagues (2007) suggest that a way of avoiding technical errors of measurement is to require all computer based programs to be run on the same system that the standardization was performed on. However, it is noted that computer systems are constantly changing and are not available over extended periods of time. Therefore the suggestion of requiring all users to obtain the same computer and OS is unreasonable (Häusler et al., 2007). This leads to the pursuit of a tool that will not be subject to the discrepancies created by computer systems, or will have significantly different results than the standardization sample due to technological differences.

ADHD has been noted to significantly impact individuals' social and emotional well being. Diagnosis of ADHD can aid in understanding and developing strategies to enhance attention and concentration levels, in order to decrease the frustration that commonly accompanies these problems, in hopes of increasing the individual's quality of life. It is important for diagnosis to be accurate, as it can affect the strategies and treatment employed in the management of ADHD. The most common means of diagnosis are self and observer reports, pen and paper assessments, and computerized measures. Objective tests, such as computerized tools, provide the clinician with great amounts of information regarding the individual's specific difficulties. Current computerized measures have shown inherent errors due to both software and hardware impacting the scoring systems. Consequently the pursuit of a precise assessment tool has lead to the development of a self-contained, electronic measure of attention that does not rely on a separate computer or operating system to present stimuli or collect results. This study will begin to explore the utility of this new test, the Stewart Machine for Attention Response Timing

(SMART), in the hopes that the SMART will make a significant contribution to the assessment of ADHD.

CHAPTER 3

Attention Deficit Hyperactivity Disorder (ADHD) is one of the most prevalent externalizing disorders that can cause impairments in attention and concentration. It can impact many aspects of an individual's educational, social, and emotional adjustment. As it is important to accurately diagnose whether an individual has ADHD, for educational, academic, social and emotional well being, it is important to use a measure that reduces as much technical error as possible. The purpose of this study is to test the validity of a new electronic measure of attention that does not rely on a separate computer or operating system to present stimuli or collect results. It is hoped that this study will make a significant contribution to the assessment of ADHD, the accuracy of diagnosis, and the utility of technologically-based measures.

Methodology

The purpose of this study is to examine the psychometric properties of the Stewart Machine for Attention Response Timing (SMART). The mixed factorial validity of the SMART, discriminant and convergent validity with the Brief Test of Attention (BTA), and the discriminant validity of the SMART between individuals with and without significant attention difficulties were examined. In this study factorial ANOVAs and independent sample t-tests were performed.

The null hypotheses were that there would be no difference in the Test Data Points, Valid Responses, Invalid Response, Omission Errors, Commission Errors, Multi Response, Mean Time, and STD Time between condition one and condition two of the SMART, there would be no difference between the four quadrants, there would be no difference between the two sample populations, there is no correlation between the BTA total scores and the SMART Mean Time,

STD Time, and total errors (i.e., the sum of the Omission Errors and Commission Errors), and that the SMART would not differentiate between people who have attention difficulties and those who do not as measured by the BTA. The alternative hypotheses are that there would be a difference on the 9 SMART scores between condition one and condition two, there would be a difference between the quadrants of the SMART, there would be a significant difference between the two sample populations, there would be a correlation between the BTA and SMART Mean Time, STD Time, and total error scores, and that the SMART would differentiate between individuals with attention problems and those without.

Specific hypotheses for this study were as follows:

1. It was expected that the SMART would have acceptable measurement properties including an approximately normal distribution on the mean and standard deviation on the 9 scales.
2. The purpose of an independent t-test study was to explore a between group comparison on the response time, variability of response time and total error SMART scores for participants from the University of Saskatchewan and students from Concordia University College of Alberta. It was expected that there would not be a significant difference between the two samples.
3. The purpose of an independent t-test study was to determine whether there is a difference between the SMART Ref Data points, Test Data Points, Valid Responses, Invalid Response, Omission Errors, Commission Errors, Multi Response, Mean Time, and STD Time scores between condition one and condition two. It was expected that there will be a significant difference between the two conditions.
4. Three factorial 2 X 4 ANOVAs were used to explore whether there is internal consistency in the means of the response time, variability of response time, and total error scores between four

quadrants, on conditions one and two of the SMART. It was expected that there would not be a significant difference between the four quadrants on these three scores.

5. The purpose of the quantitative, correlational study was to measure the concurrent validity of the SMART between the response time, variability of the response time and total error scores, and the total BTA score. The SMART response time, response time variability, and total error scores were expected to have a high negative correlation with the BTA total score.

6. Three independent sample t-tests were used on the SMART response time, response time variability, and total error scores to measure the difference between participants who have attention problems and those who do not, as identified on the BTA. It was expected that there would be a significant difference between the two groups (i.e., attention problems and no attention problems) on all three scores of the SMART condition two.

Participants

Participants in this study were 28 undergraduate university students from the University of Saskatchewan and 30 undergraduate students from Concordia University College of Alberta. The participant's ages ranged from 18 to 41, with an average age of 23.7 years old, see figure 3.1.2.1 for a box plot of the age distribution. The Saskatchewan sample was comprised of 13 male participants and 15 female participants, one of whom identified having a prior diagnosis of attention problems. The Alberta sample was comprised of 9 male and 21 female participants. Five Alberta participants reported they had a prior diagnosis of attention problems.

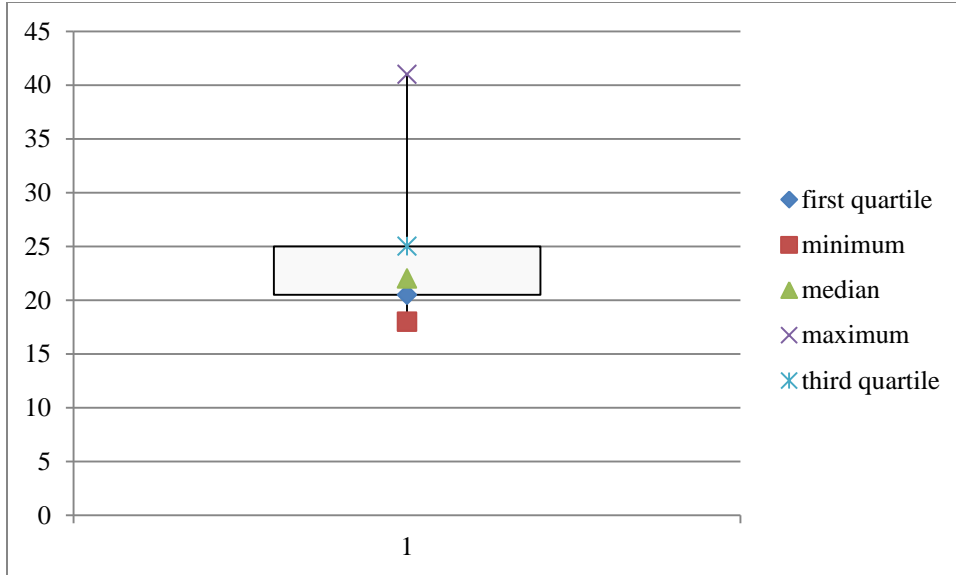


Figure 3.1.2.1 Box-plot depicting the scatter of the participants ages with the total sample.

Measures

The Brief Test of Attention (BTA).

The BTA is an auditory test of selective attention. It has been designed to be used with nonaphasic individuals aged 17 to 82. The BTA consists of a recorded voice presenting a list of numbers and letters; the examinee must relay to the examiner how many numbers were presented in each trial on Form N and how many letters on Form L. The stimuli presented in Forms N and L are identical and are comprised of two examples and ten trials. Each trial is reported as correct or incorrect, leading to a total raw score that ranges from 0 to 20. The raw score corresponds with a percentile rank, determined by age group, and is provided in appendix A of the manual.

The BTA was developed to generate a simple test of auditory sustained and selective attention “that would be sensitive to subtle attentional impairments” (Schretlen et al., 1996, p.81) based on Cooley and Morris (1990) model of sustained and divided attention. This model postulates that sustained attention tasks are comprised of attending to a specified target and inhibiting a response to a distracter. Divided attention is “understood as requiring the

performance of two simultaneous selective attention tasks” (Schretlen et al., 1996, p.81). Asloun and colleagues (2008) note that divided attention is typically considered to be connected to the performance of an individual’s working memory. Working memory is described as a controlled central executive system used for storing and manipulating information prior to encoding in long-term memory (Asloun et al., 2008; Kane & Engle, 2000; Savage, Cornish, Manly, & Hollis, 2006). Studies have shown a strong correlation between working memory and the ability to attend to two simultaneous attention tasks (Asloun et al., 2008; Kane & Engle, 2000; Savage et al., 2006).

The normative group for the BTA consisted of 667 adults from Buffalo, New York or Baltimore, Maryland who were “screened to eliminate individuals with dementia, severe psychiatric disorders, or current substance dependence” (manual, p.12). Later, 587 individuals from John Hopkins University participated in the patient sample, with diagnoses including affective disorders, schizophrenia, mental retardation, brain injury, dementia, substance dependence, eating disorders, sexual disorders, and adrenoleukodystrophy. This patient sample was used to increase internal consistency and to provide extra statistical support for the reliability of this measure. Internal consistency, estimated by coefficient alpha was measured at .90 for the complete test, .82 for form L and .81 for Form N. The between form correlation for Form N and Form L was .79, indicating that both forms are measuring the same construct (Schretlen et al., 1996). A test-retest study was completed with healthy senior adults with hypertension, yielding a correlation of .70. Several validity studies were conducted with the BTA with significant and positive correlations with the Digit Span, Trail Making Test, and the Stroop Color Word Test. Shaw (1997) reports that the BTA has a modest loading on the first factor, reflecting general and verbal mental ability, but that it loads significantly on the second factor, which reflects attentional

ability. The BTA is also reported to have a low to moderate loading on psychomotor speed and perceptual skills seen on the third factor.

Studies have been conducted to examine the efficacy of using the BTA with various populations, including, but not exclusive to, older adults, individuals with closed head injury, individuals with Huntington's disease, and children (Cooley & Morris, 1990; Des Rosiers & Kavanagh, 1978; Schretlen et al., 1996a; Schretlen et al., 1996b; Snow et al., 1988). The BTA is noted to have high long term and short term reliability amongst the various populations. Schretlen and colleagues (1996) noted that individuals with Huntington's disease are associated with severe attentional deficits. A study comparing individuals with Huntington's disease and without, demonstrated that individual's with Huntington's performed significantly weaker on the BTA than the control group. The BTA was included in a study with individuals experiencing anterograde and retrograde amnesia, who evidenced impaired learning and memory skills. The clinical and control groups in this study did not show a significant difference in their overall scores, indicating that the BTA does not rely on memory and learning skills. The current body of literature suggests that the BTA is a strong measure of attention with a variety of populations.

The Stewart Machine for Attention Response Timing (SMART).

The SMART test is an auditory test of sustained and selective attention designed to be used with nonaphasic individuals. The SMART consists of an initial tone to set the volume and ensure the participants were able to hear the tone, a recorded voice presenting a list of numbers and letters, in which the examinee must respond to a change in presented stimuli by pressing a trigger switch during two conditions. The SMART presents two four minute test conditions: initial and distracter condition. The first condition is designed to measure sustained attention; the

second condition which is identical to the first but with the addition of background story is designed to measure selective attention. Scores on nine variables are generated; the author describes and interprets these variables as:

1. Ref Data points: The reference data points are the number of target stimuli observed by SMART during a test. They are used to compare to raw data detected from the examinee.
2. Test Data Points: These are the observed trigger switch presses SMART recorded during the test.
3. Valid Responses: The total number of responses to target stimuli that fall inside the valid time period (300 to 1200 ms after the presentation of target stimuli). These times are referenced from the ref data points SMART observes during a test.
4. Invalid Response: The total number of the test data points that fall inside the time after the presentation of the stimuli to the end of invalid time (0 to 299 ms after the presentation of stimuli).
5. Omission Errors: The total number of ref data points that are not responded to by a detected button press during the valid time. Omissions are interpreted as an indicator of inattention.
6. Commission Errors: The total number of detected responses to nontarget stimuli that occurred after the valid time and before the next target stimuli. Commission errors signify disinhibition or impulsivity.
7. Multi Response: The total number of all detected responses that occurred after a valid response is detected until the end of the valid time period. While the number of responses is recorded, only the first valid response is stored as a valid response with a

time stored with it. Multiple responses may also indicate disinhibition or impulsivity, as well as potential neurological dysfunction.

8. Mean Time: The average time of all valid responses in milliseconds. The mean time is a measure of processing speed.
9. STD Time: The standard deviation of valid response times in milliseconds examines the variability of the response times. The standard deviation is a measure of sustained attention.

Scores on Condition A provide a base line for an examinee's attention and can indicate the presence of attention difficulties in sustained attention across variables five through nine. Scores on Condition B explore the same the variables with the addition of selective attention. Both condition scores can be compared to examine an individual's performance on inattention, inhibition, impulsivity and attention variability with and without a presence of a distraction.

Procedure

I complete the ethics process for the University of Saskatchewan on December 15, 2011 and obtained ethics approval from Concordia University College of Alberta on January 9, 2012. I advertised on the University of Saskatchewan's (U of S) bulletin boards and electronic classified ads, and posted advertisements at Concordia University College of Alberta (CUCA) as well as visited a variety of undergraduate psychology classroom at CUCA to introduce the study to the students. Contact information for the study was provided to the students to set up a participation time. Consent forms were provided to the student when they arrived for their participation time. The forms were read out to the participants and both the participant and I signed the consent forms. See Appendix A for a sample of the consent form. Each student was assessed individually. The student was asked to fill out a brief questionnaire based on the DSM-IV-TR

ADHD criteria to determine the number of ADHD symptoms experienced (see Appendix B), administered the two conditions of the SMART and was then administered trial 1 and trial 2 of the BTA. The participation time was estimated at 25 – 30 minutes. Each participant had their name put in a draw for a gift certificate at a local restaurant and were contacted after the data had been collected to know whether they have been selected for the gift certificate.

Preliminary Analysis

During the preliminary analysis, the accuracy of the data file was checked by reviewing the entered data against the original data, looked at the univariate descriptive frequencies to examine whether there were any scores that are falling outside of the range, and checked the means and standard deviations. I checked for any missing data and would have constructed a dummy variable with two groups, one for the missing data and one for the complete data as recommended by Tabachnick and Fidell (2007) if it was needed. As there was no missing data, I continued on with the analysis. I checked for outliers by using a box plot then rechecked the data to make sure they were entered correctly. I then changed the outlier score so that it is “one unit larger or smaller than the next most extreme score in the distribution” (Tabachnick and Fidell, 2007, p. 77). Transformations and imputations have been noted and reported in the Results section with a rationale for why the action was performed.

CHAPTER 4

RESULTS

Overview

The current study is an examination of the psychometric properties of the SMART. Data was collected from 28 university-aged students from Saskatoon, Saskatchewan and 30 university-aged students from Edmonton, Alberta. The participants were asked to complete the Brief Test of Attention, the SMART, and to fill out a short questionnaire examining common behaviours of Attention Deficit Hyperactivity/Disorder as noted by the DSM-IV-TR.

Overview of analysis

The SMART calculates eight variables for each trial, resulting in sixteen total variables to be examined. The variables calculated by the SMART are the Test Data Points, Valid Responses, Invalid Responses, Omission Errors, Commission Errors, Multiple Responses, Response Time, and Response Time Variability. Test Data Points are the number of trigger switch presses the SMART recorded during each trial. The total number of responses to the target stimuli that fall inside the valid time period (300 to 1200 ms after the presentation of target stimuli) are the Valid Responses. Invalid Responses are the number of the test data points that fall after the presentation of the stimuli to the end of invalid time (0 to 299 ms after the presentation of stimuli). The number of stimuli changes that are not responded to during the valid time are referred to as Omission Errors. Commission Errors are the total number of detected responses to nontarget stimuli. Multi Responses are the total number of all multiple responses which occur after a valid response is detected until the end of the valid time period. The SMART Mean Time is the average time of all valid responses in milliseconds. The Response Time Variability is the standard deviation of valid response times in milliseconds examines the variability of the

response times. The data was entered into SPSS 20 for analysis. Following steps laid out in Tabachnik and Fidell (2007), the data was examined and cleaned. Outliers were identified and dealt with by changing the number to one higher (or one lower) than the uppermost (lowermost) number in the data set. Normality was explored and the variables were transformed with the square root to obtain relative normality, however, the Multiple Response variables were not able to obtain normality. The descriptive statistics and distribution of each variable was examined. The mixed factorial validity of the SMART, discriminant and convergent validity with the BTA, and the discriminant validity of the SMART between individuals with and without significant attention difficulties were examined. Factorial ANOVAs and independent sample t-tests were performed to inspect the SMART's psychometric properties.

Measurement Properties

The first research question in this study was: Does the SMART have acceptable measurement properties including an approximately normal distribution on the mean and standard deviation on the 16 scales?

The descriptive statistics and distribution of each of the 16 scales was examined. Inspection of the Trial one total data, Trial one total valid responses, Trial one total invalid responses, Trial one total omissions, trial one total commissions, Trial one multiple responses, trial one response time, Trial one response time variability, Trial two total data, Trial two total valid responses, Trial two total invalid responses, Trial two total omissions, trial two total commissions, Trial two response time, and Trial two response time variability scales on the overall sample (i.e., combining the Saskatchewan and Alberta samples) revealed the data distribution met assumptions of normality. The skewness on these variables fell between the accepted cut off of 1.0 and -1.0 (Kendall & Stuart, 1958; Leech, Barrett, & Morgan, 2005).

Figures 4.2.1.1 through 4.2.1.16 displays the skewness for the 16 scales on the SMART by trials. Skewness indicates the degree which the distribution of the variables deviate from symmetry on either side of the mean. A positive skew indicates a greater number of smaller values, with more values falling below the mean, while a negative skew indicates a greater number of smaller values with more values falling above the mean. Trial two multiple response score was not able to meet the normality requirement, even after transformation, and fell just outside the 1.0 requirement at 1.04. It is hypothesized that a larger sample size would be needed to determine whether this is due to sampling bias. Inspection of the Saskatchewan and Alberta samples individually showed the Saskatchewan sample having a more positive skew on almost all of the variables except for Trial one response time and trial two total data.

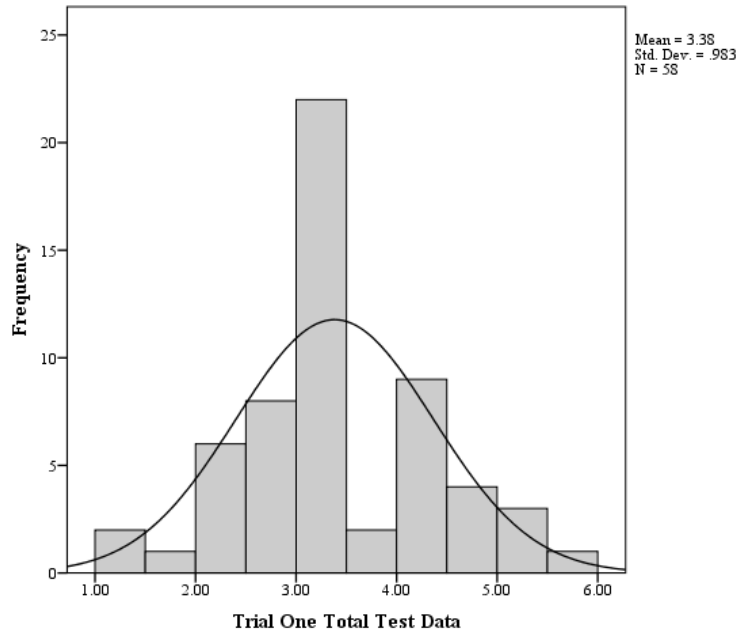


Figure 4.2.1.1. Histogram of trial one total number of trigger switch presses, with a normal curve.

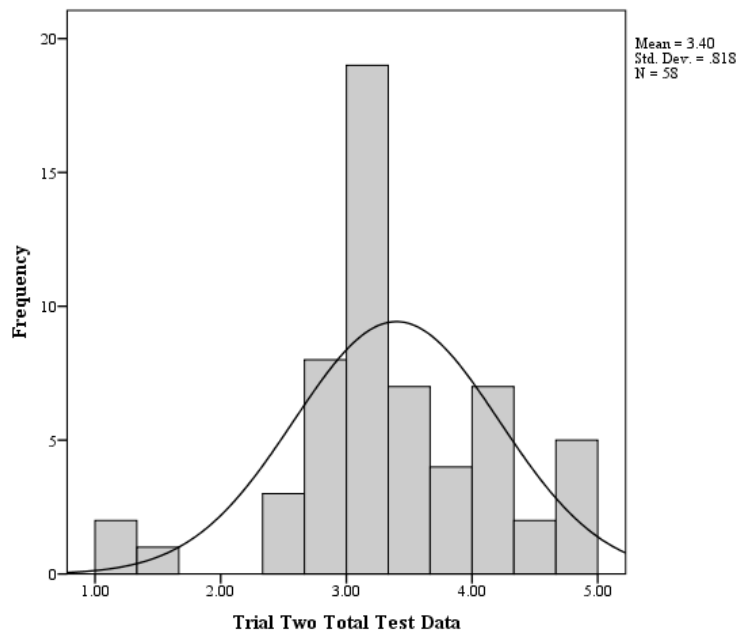


Figure 4.2.1.2. A histogram depicting the skewness of the number of total trigger switch presses during trial two with a normal curve.

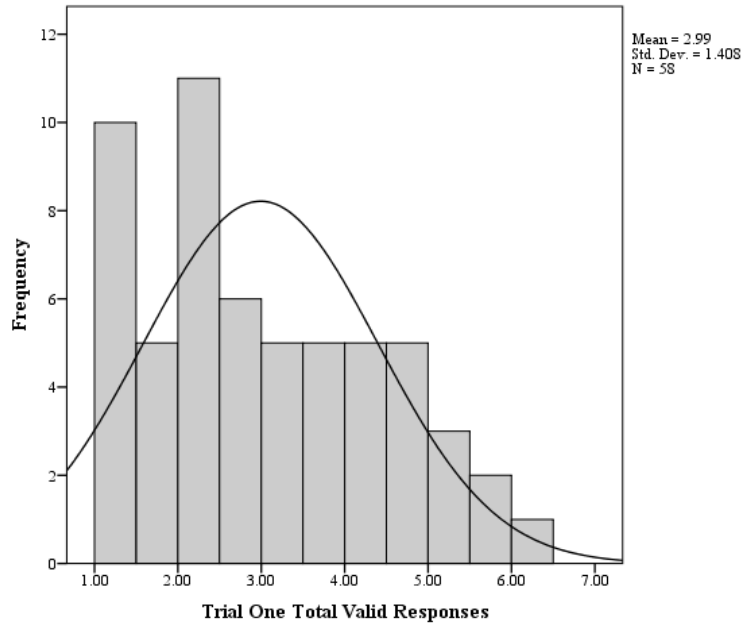


Figure 4.2.1.3. Histogram depicting the number of trigger switch presses during the valid period in trial one.

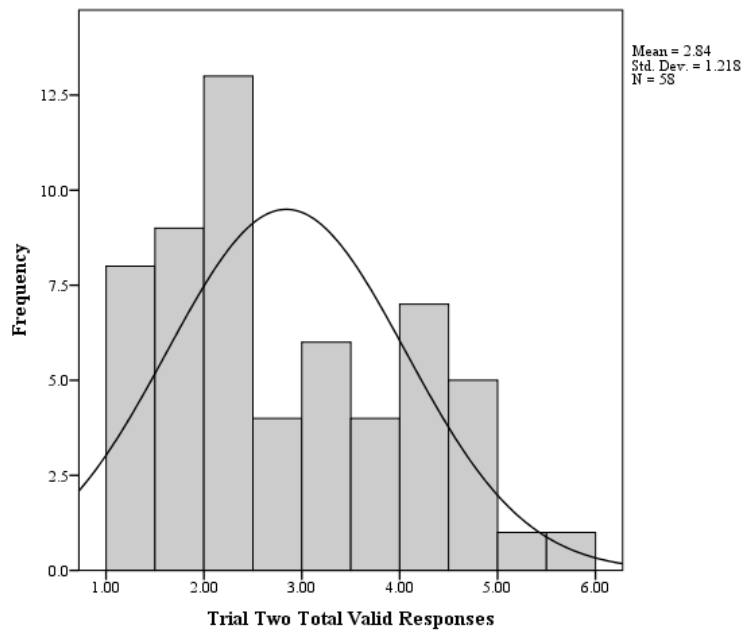


Figure 4.2.1.4. Histogram depicting the number of trigger switch presses during the valid period in trial two.

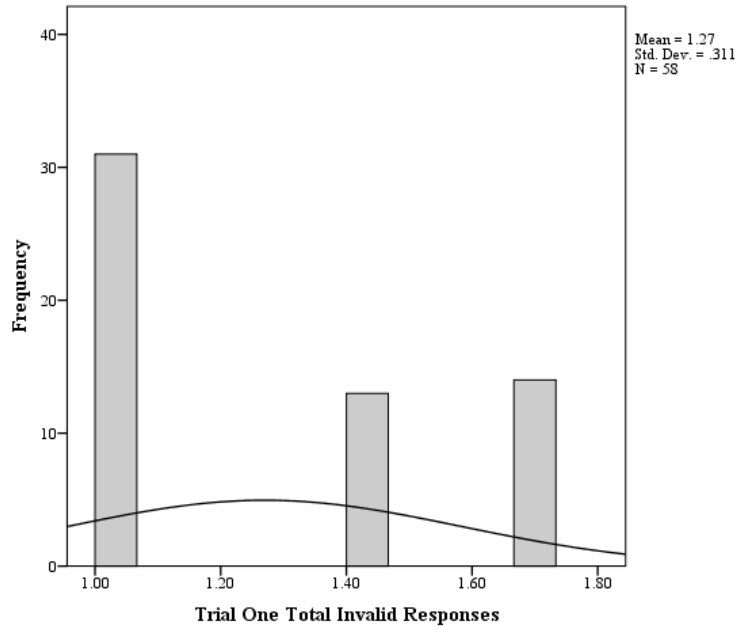


Figure 4.2.1.5. Histogram depicting the number of trigger switch presses before the valid time commenced in trial one.

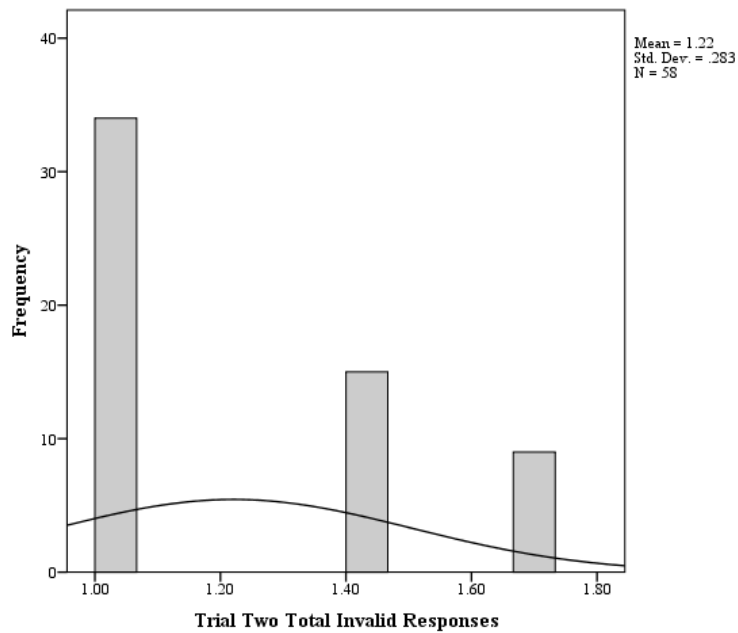


Figure 4.2.1.6. Histogram depicting the number of trigger switch presses before the valid period commenced in trial two.

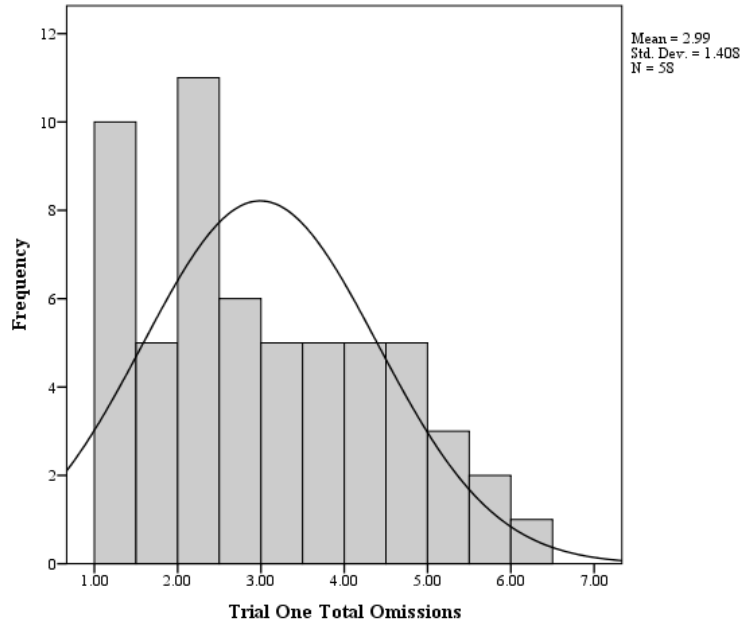


Figure 4.2.1.7. Histogram depicting the number of targets missed during trial one.

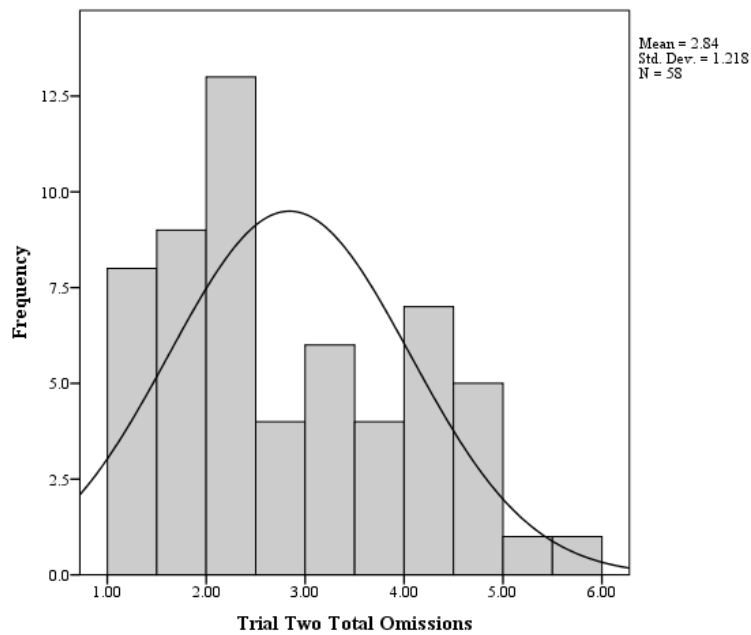


Figure 4.2.1.8. Histogram depicting the number of targets missed during trial two.

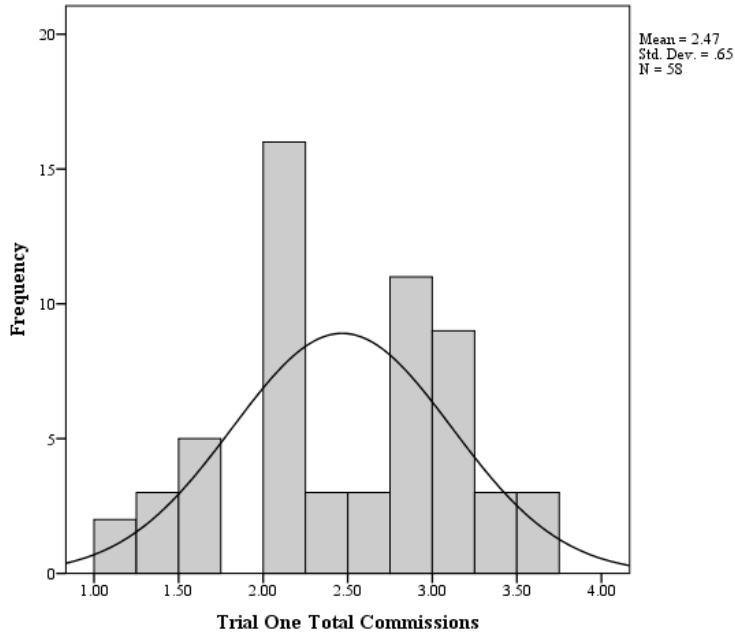


Figure 4.2.1.9. Histogram depicting the number of trigger switch presses to non-target stimuli during trial one.

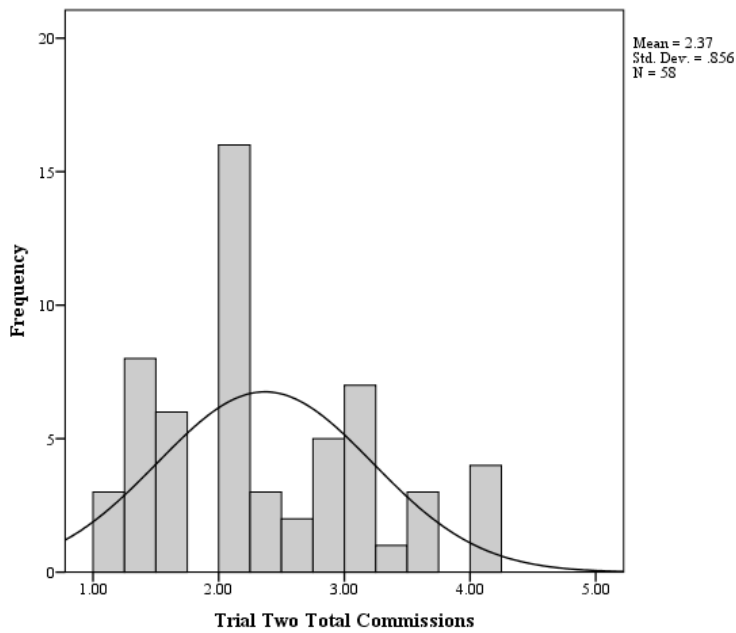


Figure 4.2.1.10. Histogram depicting the number of trigger switch presses to non-target stimuli during trial two.

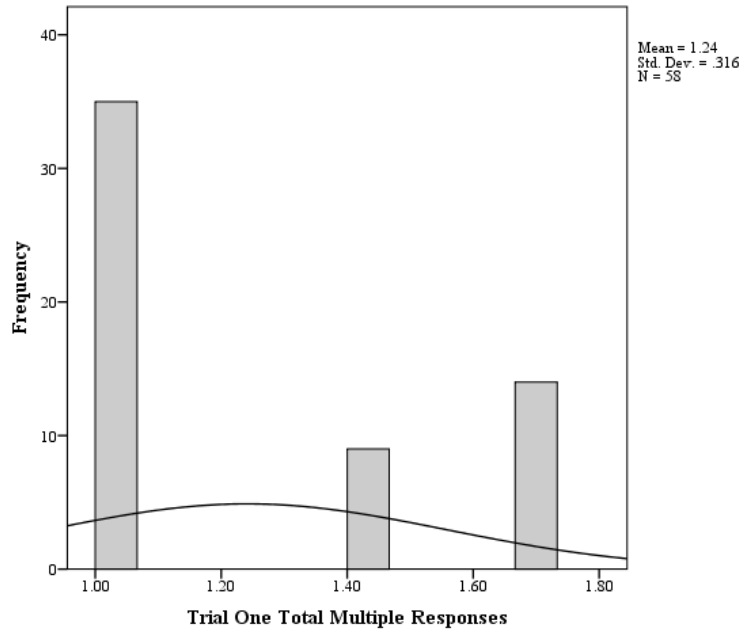


Figure 4.2.1.11. Histogram depicting the number of multiple responses during trial one.

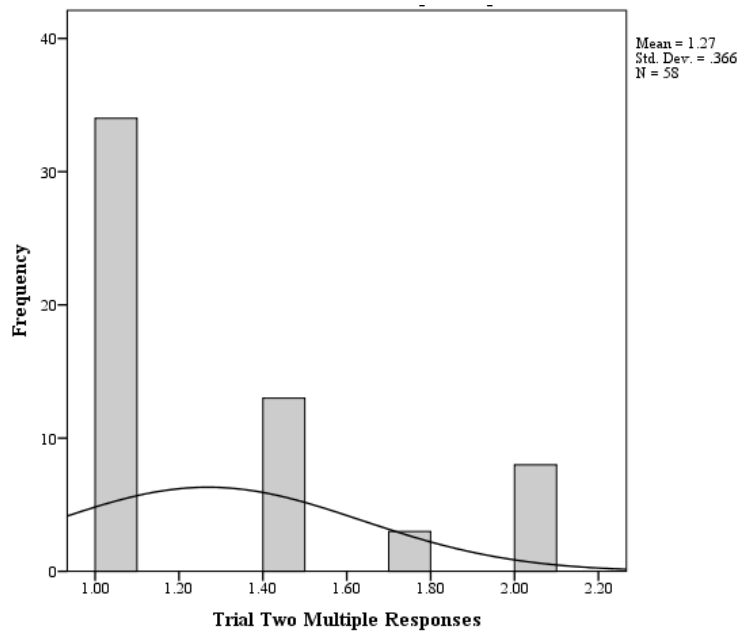


Figure 4.2.1.12. Histogram depicting the number of multiple responses during trial two.

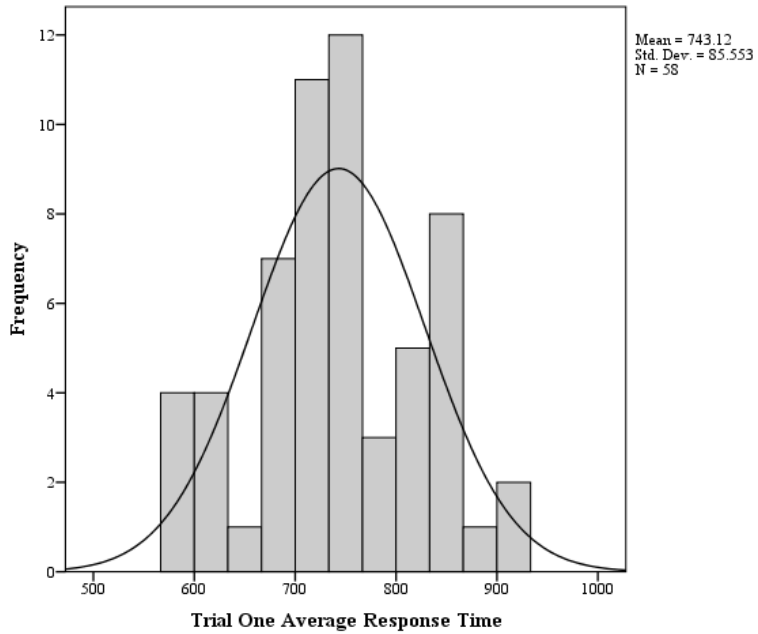


Figure 4.2.1.13. Histogram depicting the average response time to the target stimuli during trial one.

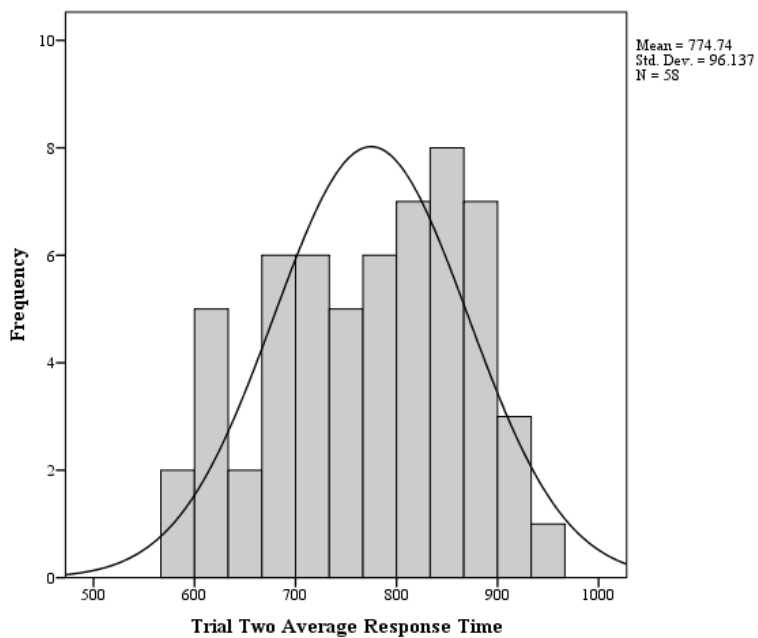


Figure 4.2.1.14. Histogram depicting the average response time to the target stimuli during trial two.

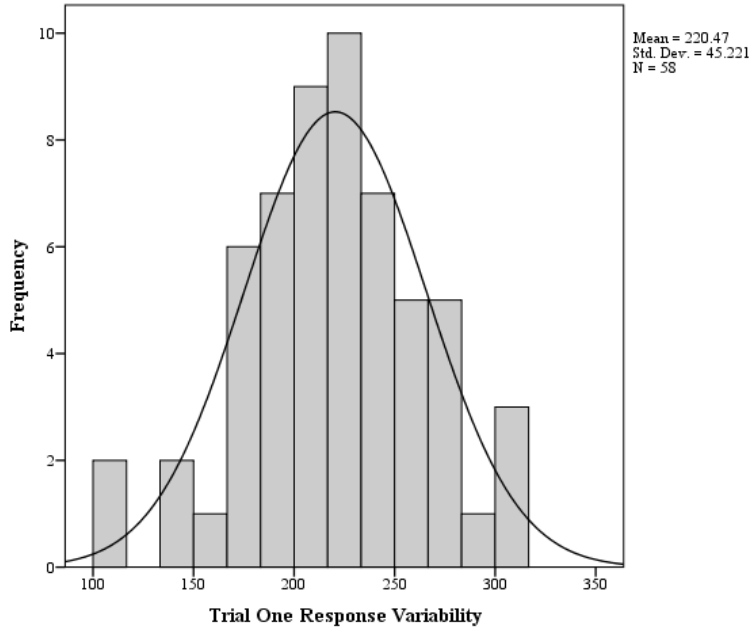


Figure 4.2.1.15. Histogram of the variability in response time to the target stimuli during trial one.

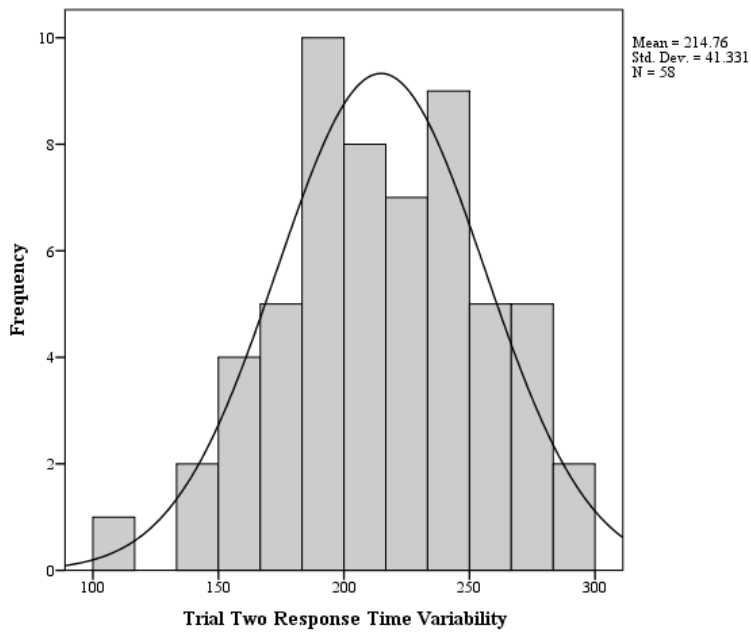


Figure 4.2.1.16. Histogram of the variability in response time to the target stimuli during trial two.

Examining the level of kurtosis on the overall sample indicated that the level of kurtosis on most scales met the assumptions of normality (Kendall & Stuart, 1958; Leech et al., 2005). However, trial one total valid response, trial one total multiple responses, and trial two total responses were leptokurtic, indicating there are more values clustered around the mean than in a normal distribution, displaying a more peaked curve than on a normal curve. Trial one total invalid responses, trial one total omissions, and trial one total multiple responses were platykurtic, indicating there are more values in the tails of the distribution than around the mean, creating a flatter curve than observed in a normal distribution. Inspection of the samples by province showed a difference in kurtosis between Saskatchewan and Alberta, in which 10 of the 16 variables had a more positive level of kurtosis in the Saskatchewan sample. The Saskatchewan sample was closer to normal on trials one and two valid responses, trials one and two invalid responses, trials one and two omissions, trial one commissions, and trial one multiple response. The Saskatchewan sample was more leptokurtic on the trial one and two total data score, and trial two multiple responses. The sample was more platykurtic on trial one response time, trials one and two response time variability, and trial two commissions.

Table 4.2.1.1 displays the descriptive statistics for the 16 scales on the SMART by trials.

Table 4.2.1.1.

Psychometric Properties of the 8 Scales on the SMART by Trials, Whole Sample (N=58)

| Variable | M | SD | Skew | Kurtosis |
|-------------------------------------|--------|-------|-------|----------|
| Trial one total data | 3.38 | 0.98 | 0.22 | 0.09 |
| Trial one total valid | 2.99 | 1.41 | 0.41 | -0.79 |
| Trial one total invalid | 1.27 | 0.31 | 0.49 | -1.48 |
| Trial one total omissions | 2.99 | 1.41 | 0.41 | -1.79 |
| Trial one total commissions | 2.47 | 0.65 | -0.21 | -0.49 |
| Trial one total multiple responses | 1.24 | 0.32 | 0.70 | -1.32 |
| Trial one response time | 743.12 | 85.55 | -0.02 | -0.46 |
| Trial one response time variability | 220.47 | 45.22 | -0.16 | 0.07 |
| Trial two total data | 3.39 | 0.82 | -0.57 | 1.70 |
| Trial two total valid | 2.84 | 1.21 | 0.46 | -0.81 |
| Trial two total invalid | 1.22 | 0.29 | 0.76 | -0.99 |
| Trial two total omissions | 2.84 | 1.22 | 0.46 | -0.81 |
| Trial two total commissions | 2.37 | 0.86 | 0.57 | -0.36 |
| Trial two total multiple responses | 1.27 | 0.37 | 1.04 | -0.034 |
| Trial two response time | 774.74 | 96.14 | -0.32 | -0.76 |
| Trial two response time variability | 214.76 | 41.33 | -0.17 | -0.34 |

Table 4.2.1.2 displays the descriptive statistics for the SMART by trials for the Saskatchewan participants. Table 4.2.1.3 illustrates the descriptive statistics of the SMART for the Albertan participants.

Table 4.2.1.2

Descriptive Statistics of SMART Variables, Saskatchewan Sample (N=28)

| Variable | M | SD | Skew | Kurtosis |
|-------------------------------------|--------|--------|-------|----------|
| Trial one total data | 3.34 | 0.77 | 0.70 | 1.50 |
| Trial one total valid | 2.57 | 1.29 | 0.70 | -0.28 |
| Trial one total invalid | 1.22 | 0.30 | 0.83 | -0.98 |
| Trial one total omissions | 2.57 | 1.29 | 0.70 | -0.28 |
| Trial one total commissions | 2.40 | 0.69 | -0.06 | -0.19 |
| Trial one total multiple responses | 1.15 | 0.26 | 1.38 | 0.45 |
| Trial one response time | 737.39 | 91.42 | -0.03 | -0.56 |
| Trial one response time variability | 222.71 | 52.78 | -0.05 | -0.46 |
| Trial two total data | 3.23 | 0.75 | -1.05 | 3.26 |
| Trial two total valid | 2.48 | 1.07 | 0.53 | -0.60 |
| Trial two total invalid | 1.21 | 0.28 | 0.87 | -0.80 |
| Trial two total omissions | 2.84 | 1.07 | 0.53 | -0.60 |
| Trial two total commissions | 2.30 | 0.90 | 0.43 | -0.94 |
| Trial two total multiple responses | 1.14 | 0.24 | 1.40 | 0.67 |
| Trial two response time | 777.21 | 104.52 | -0.32 | -0.79 |
| Trial two response time variability | 211.93 | 39.82 | -0.17 | -0.62 |

Table 4.2.1.3

Descriptive Statistics of SMART Variables, Alberta Sample (N=30)

| Variable | M | SD | Skew | Kurtosis |
|-------------------------------------|--------|-------|-------|----------|
| Trial one total data | 3.43 | 1.56 | 0.02 | -0.54 |
| Trial one total valid | 3.38 | 1.42 | 0.16 | -0.88 |
| Trial one total invalid | 1.32 | 0.32 | 0.23 | -1.74 |
| Trial one total omissions | 3.38 | 1.42 | 0.16 | -0.88 |
| Trial one total commissions | 2.53 | 0.62 | -0.35 | -0.72 |
| Trial one total multiple responses | 1.32 | 0.43 | 0.22 | -1.92 |
| Trial one response time | 748.47 | 80.90 | 0.06 | -0.26 |
| Trial one response time variability | 218.37 | 37.64 | -0.61 | 0.82 |
| Trial two total data | 3.56 | 0.86 | -0.50 | 1.22 |
| Trial two total valid | 3.18 | 1.27 | 0.28 | -1.15 |
| Trial two total invalid | 1.23 | 0.29 | 0.70 | -1.10 |
| Trial two total omissions | 3.18 | 1.27 | 0.28 | -1.15 |
| Trial two total commissions | 2.43 | 0.82 | 0.83 | -0.44 |
| Trial two total multiple responses | 1.39 | 0.42 | 0.51 | -1.44 |
| Trial two response time | 772.43 | 89.35 | -0.36 | -0.74 |
| Trial two response time variability | 217.40 | 43.21 | -0.24 | -0.01 |

Difference between Samples

The second research question was: Will there be a difference on the response time, variability of response time, total error SMART scores, current medications, number of endorsed childhood symptoms, number of endorsed adult symptoms, and prior diagnosis for participants from the University of Saskatchewan and students from Concordia University College of Alberta?

Independent t-tests were run on these three variables between the participant samples. Table 4.2.2.1 illustrates the statistical findings of the t-tests on the variables by participant samples. There was not a significant difference between the two samples on either trial one or trial two response time, variability of response time, or total error SMART scores. There was also no significant difference between the two samples in current medication, number of childhood or adult behaviours. There was a significant difference between the samples on the number of participants who have been previously diagnosed with attention problems. On average, more participants at the University of Saskatchewan ($M = 1.96$, $SE = 0.036$) reported past diagnosis of attention problems than those from Concordia University College of Alberta ($M = 1.83$, $SE = .069$), $t(56) = 1.646$, $p = .001$, $r = .22$. When accounted for, the differences between the two samples did not impact the ability to combine the Saskatoon and Edmonton samples for further statistical inspection.

Table 4.2.2.1

Differences in SMART Variables between Saskatoon and Edmonton

| | Location | | <i>t</i> | <i>df</i> |
|------------------------------|--------------------|-------------------|----------|-----------|
| | Saskatoon | Edmonton | | |
| Trial one response time | 737.39 (91.42) | 748.47 (80.90) | -.49 | 56 |
| Trial one variability | 222.71 (52.78) | 218.37 (37.64) | .36 | 56 |
| Trial one total error | 4.97 (1.83) | 5.91 (1.78) | -1.98 | 56 |
| Trial two response time | 777.21 (104.52) | 772.43 (89.35) | .19 | 56 |
| Trial two variability | 211.93 (39.82) | 217.40 (43.21) | .50 | 56 |
| Trial two total error | 4.78 (1.75) | 5.61 (1.88) | -1.74 | 56 |
| Current medication | 1.93 (.26) | 1.97 (.18) | -.65 | 56 |
| Number of childhood symptoms | 4.32 (4.10) | 4.60 (4.28) | -.25 | 56 |
| Number of adult symptoms | 4.46 (3.39) | 4.03 (2.80) | .53 | 56 |

(Continued)

Table 4.2.2.1

Differences in SMART Variables between Saskatoon and Edmonton (continued)

| | Location | | <i>t</i> | <i>df</i> |
|--------------------------------------|---------------|---------------|----------|-----------|
| | Saskatoon | Edmonton | | |
| Prior attention difficulty diagnosis | 1.96 (.19) | 1.83 (.38) | 1.65*** | 56 |

Note. *** = $p \leq .001$. Standard Deviations appear in parentheses below means.

Difference between Trial One and Two

The third research question was: Will there be a difference between the SMART Ref Data points, Test Data Points, Valid Responses, Invalid Response, Omission Errors, Commission Errors, Multi Response, Mean Time, and STD Time scores between trial one and trial two?

Descriptive statistics for these variables are displayed in Table 4.2.3.1. The descriptive statistics indicate there was only a significant difference on response time between trial one ($M = 743.12$, $SE = 11.23$) and trial two ($M = 774.74$, $SE = 12.62$) $t(57) = -3.52$, $p = .001$, $r = .72$. Indicating that the response time was significantly slower on trial two when there was the inclusion of a distracter. There were no other significant differences between the variables on trial one and trial two. This indicates that the distracter included in trial two did not make a significant impact on the performance for any of the variables except for the response time. The participants had relatively equal performances on both trial conditions.

Table 4.2.3.1

Comparative Statistics between Trial One and Trial Two on the SMART (N=58)

| | Condition | | <i>t</i> | <i>df</i> |
|---------------------------------|-------------------|-------------------|----------|-----------|
| | One | Two | | |
| Total test data points | 3.38 (0.98) | 3.40 (0.81) | -0.12 | 57 |
| Total valid responses | 2.99 (1.40) | 2.84 (1.22) | 1.08 | 57 |
| Total invalid responses | 1.27 (0.31) | 1.22 (0.28) | 1.23 | 57 |
| Total Omissions | 2.99 (1.41) | 1.84 (1.22) | 1.08 | 57 |
| Total Commissions | 2.47 (0.65) | 2.37 (0.86) | 1.15 | 57 |
| Total Multiple Responses | 1.24 (0.31) | 1.27 (0.37) | -0.59 | 57 |
| Total response time | 743.12 (85.56) | 774.74 (96.14) | -3.52*** | 57 |
| Total response time variability | 220.47 (45.22) | 214.76 (41.33) | 1.31 | 57 |

Note. *** = $p \leq .001$. Standard Deviations appear in parentheses below means.

Internal Consistency

The fourth research question was: Will there be internal consistency in the means of the response time, variability of response time, and total error scores between four quadrants, on conditions one and two of the SMART?

Three one way ANOVAs with four time quadrant groups were conducted on the aforementioned SMART variables. The SMART was divided into four one-minute time periods which are referred to as time quadrants. There was not a significant difference between the four time quadrants on the response time variability or the total error scales. There was a significant difference found within the response time variable. There was no statistical difference between time quadrants one, two and three, and two and three, however there was a statistical difference between the first three time quadrants and the fourth on trial one response time, $F(3, 228) = 342.31, p < .001$. On the trial two response time there is also a statistically significant difference between the fourth time quadrant and the other three, $F(3, 288) = 223.94, p < .001$. The length of time to respond to the stimuli was significantly shorter in the fourth time quadrant than the first three on both trial one and trial two. Tables 4.2.4.1 through 4.2.4.7 illustrate the descriptive statistics of these variables.

Table 4.2.4.1

ANOVA of Four Time Quadrants on the SMART

| Variable | Time Quadrants | | | | <i>F</i> |
|-------------------------------------|-------------------|-------------------|-------------------|-------------------|----------|
| | 1 | 2 | 3 | 4 | |
| Trial one response time | 26.34 (1.96) | 27.34 (2.03) | 27.21 (1.73) | 13.10 (4.66) | 342.31 |
| Trial one response time variability | 202.19 (65.72) | 205.09 (58.15) | 206.55 (58.65) | 211.69 (65.43) | .22 |
| Trial one total errors | 2.04 (0.62) | 2.09 (0.84) | 2.04 (0.79) | 2.11 (0.80) | .16 |
| Trial two response time | 27.51 (2.02) | 27.56 (2.11) | 27.96 (1.89) | 17.21 (4.03) | 223.94 |
| Trial two response time variability | 203.76 (61.56) | 202.50 (56.10) | 204.52 (62.09) | 198.66 (51.01) | .12 |
| Trial two total errors | 1.92 (0.72) | 1.83 (0.64) | 2.06 (0.80) | 2.16 (0.82) | 2.14 |

Table 4.2.4.2

Tukey HSD Comparisons of the Four SMART Quadrants Response Time Trial One

| Comparisons | Mean response time | SE | 95 % CI | |
|-------------|--------------------|------|-------------|-------------|
| | | | Lower Bound | Upper Bound |
| 1 vs. 2 | -1.00 | 0.53 | -2.37 | 0.38 |
| 1 vs. 3 | -0.88 | 0.53 | -2.25 | 0.50 |
| 1 vs. 4 | 13.24* | 0.53 | 11.86 | 14.61 |
| 2 vs. 3 | 0.12 | 0.53 | -1.25 | 1.49 |
| 2 vs. 4 | 14.24* | 0.53 | 12.86 | 15.61 |
| 3 vs. 4 | 14.12* | 0.53 | 12.74 | 15.49 |

Note.* = $p < 0.05$

Table 4.2.4.3

Tukey HSD Comparisons of the Four SMART Quadrants Response Time Variability Trial One

| Comparisons | Mean response time | SE | 95 % CI | |
|-------------|--------------------|-------|-------------|-------------|
| | | | Lower Bound | Upper Bound |
| 1 vs. 2 | -2.90 | 11.99 | -33.93 | 28.14 |
| 1 vs. 3 | -4.36 | 11.99 | -35.40 | 26.68 |
| 1 vs. 4 | -9.50 | 11.99 | -40.54 | 21.54 |
| 2 vs. 3 | -1.47 | 11.99 | -32.50 | 29.57 |
| 2 vs. 4 | -6.60 | 11.99 | -37.64 | 24.43 |
| 3 vs. 4 | 5.14 | 11.99 | -36.18 | 25.90 |

Table 4.2.4.4

Tukey HSD Comparisons of the Four SMART Quadrants For Total Error Trial One

| Comparisons | Mean response time | SE | 95 % CI | |
|-------------|--------------------|------|-------------|-------------|
| | | | Lower Bound | Upper Bound |
| 1 vs. 2 | -0.05 | 0.14 | -0.42 | 0.32 |
| 1 vs. 3 | 0.00 | 0.14 | -0.37 | 0.37 |
| 1 vs. 4 | -0.08 | 0.14 | -0.45 | 0.29 |
| 2 vs. 3 | 0.05 | 0.14 | -0.32 | 0.42 |
| 2 vs. 4 | -0.03 | 0.14 | -0.40 | 0.34 |
| 3 vs. 4 | -0.08 | 0.14 | -0.45 | 0.29 |

Table 4.2.4.5

Tukey HSD Comparisons of the Four SMART Quadrants Response Time Trial Two

| Comparisons | Mean response time | SE | 95 % CI | |
|-------------|--------------------|------|-------------|-------------|
| | | | Lower Bound | Upper Bound |
| 1 vs. 2 | -0.05 | 0.49 | -1.33 | 1.23 |
| 1 vs. 3 | -0.45 | 0.49 | -1.73 | 0.83 |
| 1 vs. 4 | 10.29* | 0.49 | 9.01 | 11.57 |
| 2 vs. 3 | -0.40 | 0.49 | -1.68 | 0.88 |
| 2 vs. 4 | 10.34* | 0.49 | 9.06 | 11.62 |
| 3 vs. 4 | 10.74* | 0.49 | 9.46 | 12.02 |

Note. *= $p < 0.05$

Table 4.2.4.6

Tukey HSD Comparisons of the Four SMART Quadrants Response Time Variability Trial Two

| Comparisons | Mean response time | SE | 95 % CI | |
|-------------|--------------------|-------|-------------|-------------|
| | | | Lower Bound | Upper Bound |
| 1 vs. 2 | 1.26 | 10.75 | -26.55 | -29.07 |
| 1 vs. 3 | -0.76 | 10.75 | -28.57 | -27.05 |
| 1 vs. 4 | 5.10 | 10.75 | -22.71 | 32.91 |
| 2 vs. 3 | -2.02 | 10.75 | -29.83 | 25.79 |
| 2 vs. 4 | 3.84 | 10.75 | -23.96 | 31.65 |
| 3 vs. 4 | 3.84 | 10.75 | -21.95 | 33.67 |

Table 4.2.4.7

Tukey HSD Comparisons of the Four SMART Quadrants Total Error Trial Two

| Comparisons | Mean response time | SE | 95 % CI | |
|-------------|--------------------|------|-------------|-------------|
| | | | Lower Bound | Upper Bound |
| 1 vs. 2 | 0.09 | 0.14 | -0.27 | 0.45 |
| 1 vs. 3 | -1.37 | 0.14 | -0.50 | 0.22 |
| 1 vs. 4 | -0.24 | 0.14 | -0.60 | 0.12 |
| 2 vs. 3 | -0.22 | 0.14 | -0.58 | 0.13 |
| 2 vs. 4 | -0.32 | 0.14 | -0.68 | 0.04 |
| 3 vs. 4 | -0.10 | 0.14 | -0.46 | 0.26 |

Comparing the SMART and the BTA

The fifth research question asked: Is there concurrent validity of the SMART between the response time, variability of the response time and total error scores, and the total BTA score?

Table 4.2.5.1 depicts the descriptive statistics of the variables on trial one and trial two of the SMART and the BTA. There is medium concurrent validity between BTA and the number of errors on the SMART, total error trial one $r = -.41$, $p \leq .001$ and total errors trial two $r = -.39$, $p \leq .001$. There is small to medium concurrent validity between BTA and response time trial one, $r = -.26$, $p < .05$ and the trial two response time variability, $r = -.26$, $p < .05$.

Table 4.2.5.1

Correlation between BTA and SMART Variables

| | Trial | |
|---------------------------|--------|--------|
| | One | Two |
| Response time | -.26** | -.18 |
| Response time variability | -.20 | -.26* |
| Total error score | -.41** | -.39** |

Note * = $p \leq .05$, ** = $p \leq .01$

Discrimination between Identified Attention Problems

The research question formulated for discrimination was: Does the SMART response time, response time variability, and total error scores measure the difference between participants who have attention problems and those who do not, as identified on the BTA?

The independent sample t-tests depicted there was not a significant difference between the SMART response times or response variability times for the participants identified with attention difficulties on the BTA. There was a significant difference on the total error scores between the participants identified with attention difficulties as identified on the BTA ($M= 6.89$, $SE=.80$) and without ($M=4.98$, $SE=.24$), $t(56)=2.70$, $p<.01$, and represented a medium-sized effect $r= -.36$. This suggests the SMART trial two total error score variable discriminates between individuals with attention difficulties as identified by the BTA. The descriptive statistics are portrayed in Table 4.2.6.1.

Table 4.2.6.1

Comparing SMART Scores for Individuals With and Without Attention Difficulties

| | Attention Difficulties | | <i>t</i> | <i>df</i> |
|-------------------------|------------------------|-------------------|----------|-----------|
| | Yes (N=7) | No (N=51) | | |
| Trial two response time | 815.00 (100.01) | 769.22 (95.28) | 1.19 | 56 |
| Trial two variability | 240.00 (42.62) | 211.29 (40.35) | 1.75 | 56 |
| Trial two total error | 6.89 (2.12) | 4.98 (1.71) | 2.70** | 56 |

Note. ** = $p \leq .01$. Standard Deviations appear in parentheses below means.

Summary

Exploration of the statistical properties of the SMART was conducted to answer the six research questions. Most of the transformed scores fell within the requirements of normality, however, there were a few scores that did not meet the requirements of normality and will require further research. There was not a significant difference between trial one and trial two except on the response time variable, indicating that the distracter included in trial two does not make a significant difference on the performance of most variables on the SMART. Inspection of the four quadrants on the response time, variability of response time, and total error scores on conditions one and two revealed internal consistency on all measures except for the response time variable. The response time variable showed internal consistency on the first three quadrants, however, had a significant difference on the fourth quadrant in which the response time was much quicker. Inspection of whether there was a difference between the Saskatchewan sample and Alberta sample did not reveal a significant difference on the performance on the SMART, the number endorsed childhood or adult attention difficulty symptoms, nor whether they were currently on medication that impacts attention. There was a significant difference on the number of participants who have had a previous diagnosis of attention difficulties, in which there were a greater number of Saskatchewan participants with diagnosed attention problems. Exploration of the concurrent validity between the BTA and the SMART revealed significant correlations between the BTA and the response time, response time variability and total error scores, with the strongest relationship with the total error score. The SMART trial two response time, response time variability, and total error scores were explored to determine whether they discriminate between participants who have attention problems and those who do not, as identified on the BTA. The total error score showed utility in identifying individuals who have

attention difficulties as identified by the BTA. Chapter 5 will examine each of these questions in greater detail and explore future research opportunities.

CHAPTER 5

DISCUSSION

The current study is an examination of the psychometric properties of the Stewart Machine for Attention Response Timing (SMART). Fifty-eight undergraduate university students aged 18 to 41, with an average age of 23.7 years old, participated in the study. Twenty-eight university students from Saskatoon, Saskatchewan and thirty university students from Edmonton, Alberta participated in the study. The Saskatchewan sample was comprised of 13 male participants and 15 female participants, one of whom identified having a prior diagnosis of attention problems. The Alberta sample was comprised of 9 male and 21 female participants. Five Alberta participants reported they had a prior diagnosis of attention problems.

The participants were asked to complete the SMART, the Brief Test of Attention (BTA), and to fill out a short questionnaire examining common behaviours of Attention Deficit Hyperactivity/Disorder (ADHD) as listed by Diagnostic and Statistical Manual of Mental Disorders – Fourth Revision – Text Revision (DSM-IV-TR). The psychometric properties the SMART were examined and compared with the BTA and the number of ADHD symptoms experienced in childhood and adulthood.

The SMART test is composed of two trials of the same stimuli presentation. The second presentation includes a distracter story which runs alongside the stimuli presentation. Eight variables are produced by the SMART for both trials one and two, resulting in 16 calculations per complete SMART administration. The variables calculated by the SMART are the Test Data Points, Valid Responses, Invalid Responses, Omission Errors, Commission Errors, Multiple Responses, Response Time, and Response Time Variability. Test Data Points are the trigger switch presses the SMART recorded during the test. Valid Responses are the total number of

responses to the target stimuli that fall inside the valid time period (300 to 1200 ms after the presentation of target stimuli). Invalid Responses are the total number of the test data points that fall inside the time after the presentation of the stimuli to the end of invalid time (0 to 299 ms after the presentation of stimuli). The SMART Omission Errors are the total number of stimuli changes that are not responded to during the valid time. Omissions may be interpreted as an indicator of inattention. Commission Errors are the total number of detected responses to nontarget stimuli. Commission errors signify disinhibition or impulsivity. Multi Responses are the total number of all multiple detected responses which occur after a valid response is detected until the end of the valid time period. While the number of responses is recorded, only the first valid response is stored as a valid response with a time stored with it. Multiple responses may also indicate disinhibition or impulsivity, as well as potential neurological dysfunction. The SMART Mean Time is the average time of all valid responses in milliseconds. The mean time is a measure of processing speed. The Response Time Variability is the standard deviation of valid response times in milliseconds examines the variability of the response times. The standard deviation is a measure of sustained attention.

The descriptive statistics and distribution of each of the 16 scales was examined with the individual samples (i.e., Saskatchewan and Alberta) and the combined overall sample. Inspection of the Saskatchewan and Alberta samples individually showed the Saskatchewan sample having a more positive skew on almost all of the variables except for Trial one response time and trial two total data. This indicates that the Saskatchewan sample had more values above the mean or fewer values below the mean than the Alberta sample. The majority of the Saskatchewan variables and all of the Alberta variables had skewness between 1.0 and -1.0, indicating a relatively normal distribution for both samples.

Examination of the levels of kurtosis by province showed a difference between the Saskatchewan and Alberta samples in which 10 of the 16 Saskatchewan variables had more positive levels of kurtosis (i.e., the values near the mean occurred more frequently than would be expected in a normal distribution). The Saskatchewan sample was closer to mesokurtic (the shape of a normal curve) on trails one and two valid responses, trials one and two invalid responses, trials one and two omissions, trial one commissions, and trial one multiple response. It was more leptokurtic on the trails one and two total data scores, and trial two multiple responses, indicating that the values obtained around the mean occurred more frequently than would be expected in a normal distribution. As well, the sample was more platykurtic on trial one response time, trials one and two response time variability, and trial two commissions, indicating that the values obtained on these variables occurred less frequently than would be expected in a normal distribution. Platykurtic distributions on these variables show that there are more values located in the tails of the distribution than around the mean.

Independent t-tests were run on the SMART comparing the means of the variables between the two participant samples. There was not a significant difference between the two samples on either trial one or trial two response time, variability of response time, or total error SMART scores. There was also no significant difference between the Saskatchewan and Alberta samples on the current medication, number of endorsed childhood or adult behaviour variables. On average, more participants at the University of Saskatchewan reported past diagnosis of attention problems than those from Concordia University College of Alberta. Even when accounting for the difference with past diagnosis, there were no significant differences between the Saskatchewan and Alberta samples. As such, the samples were combined and the overall sample was used in the exploration of the statistical properties of the SMART.

Inspection of the overall sample (i.e., combining the Saskatchewan and Alberta samples) Trials one and two total data, Trials one and two total valid responses, Trials one and two total invalid responses, Trials one and two total omissions, trials one and two total commissions, Trial one multiple responses, trials one and two response time, and Trials one and two response time variability revealed the data distribution met assumptions of normality. The skewness on these variables fell between 1.0 and -1.0. The Trial two multiple responses variable was not able to meet the normalcy requirement, even after transformation, and fell just outside the 1.0 requirement at 1.04 (Kendall & Stuart, 1958; Leech et al., 2005). It is hypothesized that a larger sample size would be needed to determine whether this is due to sampling bias.

Examination of the level of kurtosis on the overall sample indicated that the level of kurtosis on most scales met the assumptions of normality. However, trial two total responses was leptokurtic with an positive excess kurtosis of 1.70, indicating that the values obtained around the mean occurred more frequently than would be expected in a normal distribution. Trial one total valid and invalid responses, trial one total omissions, and trial one total multiple responses were platykurtic with negative excess kurtosis less than -1.48, indicating that the values obtained on these variables occurred less frequently than would be expected in a normal distribution.

The SMART was designed with two trails; trial one requiring the participant to respond to the changing stimuli in a correct and quick manner, trial two, completing the same task with a distracter present in the background throughout the administration. It was hypothesized that the participants would have greater difficulty completing the task on trial two with the presence of the distracter, thus affecting all the trial two scores. It was hypothesized there would be a greater number of Test Data Points, Invalid Response, Omission Errors, Commission Errors, and Multi Responses, with fewer Valid Responses. As well, it was hypothesized that the Mean Time and

STD Time scores would increase on trial two. The statistical examination showed that there were slight differences in the variable but the only one that had a significant difference between trial one and trial two was on the response time variable. As was hypothesized, the participants had a slower response time on trial two when the distracter was present. The total test data points and total multiple responses were slightly higher and the number of valid responses decreased on trial two but not to a degree to indicate that the distracter making a marked impact on the participant's performance. Contrary to the hypothesis, the number of invalid responses, omissions, commissions, and response time variability decreased in trial two, indicating the participant's were more accurate in their responses and had a more consistent responding rate when there was the distracter was present. It was interesting to note that most of the participants commented they felt it was easier to concentrate on the second trial as they were able to actively concentrate by ignoring the distraction task. Many of the participants recalled similar parts of distracter, including the name of the character, that he was chasing butterflies and came across a humble bee. The participants indicated that they were able to concentrate on the task during the rest of the presentation and did not find the distracter story engaging. It was also noted that the volume of the distracter story was such that the participants could ignore it easily. One of the participants indicated he would find the task more difficult if the distracter story was presented in the same voice as the task stimuli.

The empirical evidence, the statistical computations of the participants' scores and the participants' experience, implies that there is no overall difference between the two trials. It appears that in order for the SMART trial two to be significantly more taxing on an individual's ability to concentrate, the distracter stimuli must be altered. Further studies can incorporate a louder presentation of the distracter story, the reading of the story in the same voice as the task

stimuli, or a more engaging story. Of note, many of the participants indicated they typically study or engage in focused work with music playing or in a loud setting. This may have influenced their performance on the SMART as they previously developed concentration skills in the midst of environmental stimuli. Further studies could include comparing the performance of individuals who typically work in a noisy environment versus those who do not.

Internal consistency was explored on trial one and two response time, response time variability, and total error scores between the four time quadrants. It was hypothesized that there would not be a difference, with the time quadrants presenting a similar level of challenge resulting in consistent scores. It was also surmised that the participant's performance would wane as the task progressed. There was no statistical difference between the four quadrants on the response time variability or total error scales, indicating internal validity on these variables. A significant difference did appear within the response time variable, indicating a marked difference on at least one of the quadrants of this variable. No significant differences were found between quadrants one, two and three, and two and three, however there was a statistically significant difference between the first three quadrants and the fourth on both trials one and two response times. The response times in quadrant four were markedly faster than the response times recorded for the other three quadrants, indicating that there is an aspect to the fourth quadrant that makes it easier to respond in a quick manner. As both trial one and trial two are similar in this respect, it can be assumed that the difference is not due to a change in the distracter, but is in fact within the task itself. Inspection of the stimuli presentation would need to occur to determine whether there is a similar level of difficult changes and the order of the changes. A different stimuli presentation order may be required to rectify the significant difference. Participants may have become familiar with the task and developed a strategy by the

fourth quadrant which enhanced their performance, as such, in a further study it would also be beneficial to alter the order of the quadrants to determine if the difference is due to a practice effect.

In addition to exploring the internal psychometric properties of the SMART, a comparison was made with the Brief Test of Attention (BTA). The BTA is an auditory measure of sustained and selective attention, sensitive to inhibition and attending. Concurrent validity was examined between the SMART response time, variability of the response time and total error scores (total errors are comprised of the omission errors and the commission errors), and the total BTA score through a correlational study. It was hypothesized there would be significant negative correlations between the SMART variables and the BTA. The BTA was selected because it is comprised of attending to a specified target and inhibiting a response to a distracter over a sustained period of time. It was hypothesized that individuals with attention difficulties would have greater difficulty maintaining attention to the SMART task, thus increasing their response time and experiencing a greater variability in their response time, the response time variability is a measure of sustained attention. As well, the number of errors recorded by the SMART are considered a marker of attention difficulties. The omission errors are interpreted as an indicator of inattention and the commission errors signify disinhibition or impulsivity.

The results indicate that there is a significant negative correlation between the total error score and the total BTA score (as the total number of errors on the SMART increased, while the total number of correct responses on the BTA decreased), and showed to have medium concurrent validity. Significant negative correlations were also found between the BTA and response time trial one, and the trial two response time variability, with small to medium concurrent validity. These findings are consistent with the hypothesis that the SMART and BTA

would have significant negative correlation on the variables, as both tools are intended to measure selective sustained attention, inhibition, and attending. It was hypothesized that the SMART would have higher sensitivity to difficulties in these areas as it incorporates response time variables, leading to greater accuracy than the BTA which does not measure response time. Further research incorporating other measures with time sensitive tasks to examine the sustained attention, inhibition, and attending variables is recommended to help establish the SMART's utility in accurately assessing attention difficulties.

It was hoped that there would be a greater level of correlation between the variables, however, this study shows a significant relationship that warrants further research. It would be beneficial for future studies to explore the relationship between the separate categories of error and the BTA to determine if one or the other has stronger concurrent validity. A correlational study including a clinical sample would be advantageous in determining the concurrent and convergent validity of the SMART with the BTA and other attention tools. Studies of this nature are beneficial as they provide more information on the utility of the SMART in identification of individuals with attention problems. It is hypothesized that the SMART would show high concurrent and convergent validity with other tests of attention that assess similar variables. If the SMART shows high correlations with multiple tests, it could potentially be used to replace these tests, thus reducing assessment time (i.e., the time it takes to administer the SMART as compared to multiple tests that measure the same constructs) and costs of owning and utilizing multiple tests for one assessment. Further research could also focus on comparing the SMART with other psychometric measures to explore divergent validity for tasks that theoretically are diverse from the SMART (i.e., memory or I.Q. tasks).

The SMART response time, response time variability, and total error scores were explored to determine whether they measure the difference between participants who have attention problems and those who do not, as identified on the BTA. A cut-off score of one standard deviation below the mean on the BTA was used to identify participants with attention difficulties. Independent sample t-tests were run on the SMART response time, response time variability, and total error scores comparing the individuals with attention difficulties and without. The results did not indicate a significant difference between the response time or variability of response time scores between the participants with and without attention difficulties. There was, however, a significant difference between participants identified with attention difficulties on the total error score variable. This suggests that the SMART discriminates between individuals who have attention difficulties as identified by the BTA on the Trial two total error score. This corroborates with the concurrent validity between the BTA and the SMART, indicating that the SMART total error score is a good measure of attention.

There were a limited number of participants who indicated prior attention difficulties (6 of the 58 participants), or who scored below the cut-off on the BTA (7 of 58 participants fell below the cut off standard score of 85). Although the SMART showed efficacy in differentiating between attention difficulties and not, this may reflect a sampling bias due to a small sample size. Future research incorporating a larger sample would be beneficial, as well as including a clinical population to compare with the non-clinical population. It would also be beneficial to explore the efficacy of the SMART with younger populations as well, as noted above the percent of individuals with attention difficulties wanes as people age. As such, a younger population may show more significant results than an older one. Additional examination of the SMART with the

subtypes of attention deficit disorder could lend further information into the SMART's usefulness in identifying individuals with specific attention difficulties.

It was noted that the number of attention difficulties experienced as a child showed high correlation with trial two total invalid, mean and total error variables, whereas the adult symptoms endorsed demonstrated a high correlation with trials one and two commissions and the total mean. A positive correlation between these variables was observed, indicating that the higher the number of ADHD symptoms, as identified by the DSM-IV-TR, the participants endorsed, a greater number of invalid responses and errors occurred, and the mean response time increased. A breakdown of the specific attention difficulties compared to the SMART variables was not conducted. Further research investigating the specific types of self-reported attention difficulties may indicate a relationship between the type of attention symptoms and the performance on certain aspects of the SMART. Studies of this nature could indicate the utility of the SMART in identifying specific types of attention difficulties and can be used in the diagnosis and treatment planning for individuals with ADHD.

Data from this pilot study can be used to determine the number of participants needed to validate the SMART. Effect size (the magnitude of an observed effect) is examined in determining whether a variable or construct is meaningful, it is linked to the sample size, the probability the effect is statistically significant (α), and power (Field, 2009; Tabachnick and Fidel, 2007). Power is the probability the test will find an effect in a population if an effect exists. A common level of power is set at .8 (Field, 2009; Tabachnick and Fidel, 2007), indicating the test has an 80% chance of detecting the effect if it exists. A commonly accepted level of statistical significance is at the 95th percentile, with an α of .05. As the effect size observed between individual's with attention difficulties and without in this study fell within the

medium range (Cohen, 1988), it was used as a benchmark for calculating the number of participants required for further studies. The results from this study indicate that at least 128 people would need to participate in a further two-tailed study, to validate the SMART. Using Cohen's d of .05, and power set at 0.8, it was calculated that a minimum sample of 64 participants in each group (with attention difficulties and without) would provide a reliable measure of validity for the SMART.

It is of note to mention that there was difficulty with the equipment on some of the administrations about 10 seconds into the tasks when the battery began to run low on power. The SMART powered down when three participants responded to the first change in stimuli (i.e., pressing the response button). The participants agreed to wait a few minutes while the SMART was recharged and began the administration again. It is not believed that restarting the task affected the resulting scores, as the section discontinued as soon as the participant initiated their first response. There was not a period of extra practice as compared to the participants whose administration was not interrupted, nor was there an extended time using the SMART machine to impact the variability of overall response time. It is recommended that a more reliable platform be incorporated into the SMART, specifically with a power meter to indicate when the battery life is reaching a low point. Future studies could include measuring the results of the participants during the first half of the battery life to the second half (or a similar breakdown) to determine whether there is a significant impact of the power source to the administration and response recording of the SMART.

Further research could also include a screening for hearing impairments, exploring a baseline for auditory performance. Normative samples could include normal hearers and non-

normal hearers. Adjustments in signal strength and tone could be incorporated to compensate for each individual's hearing range to ensure that all participants hear the same stimuli.

The psychometric properties of the SMART were explored. Most of the transformed scores fell within the requirements of normality. There was not a significant difference between the Saskatchewan and Alberta samples except for the number of participants who have had a previous diagnosis of attention difficulties, in which there were a greater number of Saskatchewan participants with diagnosed attention problems, as such the difference in attention was accounted for and the samples were combined for the statistical analysis of this study. Comparison of trials one and two of the SMART revealed that there was only a significant difference between trial one and trial two on the response time variable, indicating that the distracter included in trial two does not make a significant difference on the performance of most variables on the SMART. Inspection of the four quadrants on condition one and condition two showed internal consistency on all measures except for the response time variable. Although there was consistency between the first three quadrants, the response time was much quicker in the fourth. There were significant correlations between the BTA and the response time, response time variability and total error scores, with the strongest relationship with the total error score. The SMART trial two total error score showed utility in identifying individuals who have attention difficulties as identified by the BTA.

Further research incorporating the new criteria included in the DSM-5 would be beneficial in determining the utility of the SMART in diagnosing ADHD. The new criteria (including the higher age cut-off, categorizing the individual based on presentation and not subtype, and change in the number symptoms required) may allow for more adults to qualify for diagnosis. Further research, using these criteria to identify the clinical participants, could aid in

determining the SMART's utility of diagnosis and analyzing the severity of the participant's symptoms. The SMART may also help adults whose diagnosis is ADHD in remission, if they currently meet partial requirements but still display difficulties with attention and concentration, to identify areas for treatment and planning. The SMART shows the potential to be an efficient attention test, exploring various areas of attention in one administration. A more advanced study would help identify the psychometric properties and establish validity for various populations and ages.

Attention Deficit Hyperactivity Disorder (ADHD) is one of the most prevalent externalizing disorders that can cause impairments in attention and concentration and can have a significant impact in an individual's social and emotional well being. Diagnosis of ADHD can aid in understanding and developing strategies to enhance an individual's attention and concentration levels, thus lowering the frustration that commonly accompanies these problems and increasing the quality of life. As it is important to accurately diagnose ADHD, for educational, academic, social and emotional well being, it is important to use a reliable and valid measure. This pilot study showed internal consistency in the SMART as well as efficacy in identifying individuals with attention difficulties. The SMART shows great promise in the identification of attention difficulties, and will need further research once the technical complications and presentation difficulties are addressed. A tool such as the SMART could be beneficial for the technician and individuals with ADHD as it can identify various area of attention that the individual is presenting with. It can indicate the severity in the areas the individual is experiencing difficulties, thus leading to more accurate diagnosis and appropriate treatment options. As the SMART explores various aspects of attention and concentration, it shows the potential of minimizing the number of measurements administered in an assessment,

shortening the overall assessment time and decreasing the number of separate assessment tools the clinician is required to purchase. Further research will assist in the establishment of this computerized tool, leading to accurate identification and treatment options for individuals with ADHD.

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Appendix A

LETTER OF CONSENT FOR RESEARCH STUDY: SMART: Pilot Validity

Study of a New Attention Test

You are invited to participate in the research project entitled, SMART: Pilot Validity Study of a New Attention Test. Please read this form carefully and feel free to ask any questions you might have. The purpose of the study will be to explore the validity of the SMART in identifying attention problems. Participation is not part of the individual health care and/or medical treatment. Your participation is optional. You may withdraw at any time, for any reason without any negative repercussions or penalty. In order to protect the interests of the participants I will adhere to the following guidelines:

1. The researcher will administer the SMART and the BTA.
2. You will be tested once with each tool and the results will be recorded. The researcher will acknowledge that you can withdraw at any time during the study without penalty. If you withdraw, the data collected from the recordings will be destroyed.
3. You will be asked to fill out a brief questionnaire that will ask about your personal demographics, attention behaviours and the presence of attentional/behavioural diagnosis.
4. The data collected from you will be kept in a secure place and will be held at the University of Saskatchewan with Dr. Tim Claypool in the Department of Educational

Psychology, for 5 years. Any contributions made will be kept confidential and specific results will not be shared with anyone outside the research team.

5. The results of the study will be used to write a thesis to fulfill the requirements of Masters of Education. The confidentiality and anonymity of you and your information will be protected through the use of coding. Although the data from this research project will be published and may presented at conferences, the data will be reported in summative form, so that it will not be possible to identify individuals. As well, the Consent Forms will be stored separately from the SMART and BTA forms, so that it will not be possible to associate a name with any given set of responses.
6. Your participation would involve 1 session, which will last approximately 30 minutes.
7. You will be informed of any new information that may affect your decision to participate.

In appreciation for your time, your name will be entered into a draw for one of 4, \$50 gift certificates, and you will be notified by email if your name was drawn.

Upon completion of the study, you will be contacted by email with a brief summary of the results of the study. You will also be provided with an electronic link to the complete document.

If you have any questions about your participation or your rights as a participant this study, you may contact the Office of Research Services at the University of Saskatchewan (966-2084) or you can contact me, Karen Brodie, at (306) 717-8289, my supervisor, Dr. Tim Claypool, Department of Educational Psychology, (306) 966-9631 or Dr. Garth Stewart (780) 474-0341.

I, _____ understand that this research project has been approved by the University of Saskatchewan Behavioural Research Ethics Board December 15, 2011 and I agree

to participate. I am aware of the nature of the study and understand what is expected of me and I also understand that I am free to withdraw at any time throughout the study without penalty. A copy of this form has been given to me for my records and at the end of the study I will receive a copy of the report. _____(initials)

(Date)

(Date)

(Participant signature)

(Researcher's signature)

(Participant email)

Appendix B

Participant _____ (code) _____ Date: _____

Age: _____ Gender: _____ Years of Schooling: _____

Please mark off any that apply:

| | As a child (i.e., before the age of 7) | As an adult |
|---|--|-------------|
| Fail to give close attention to details or make careless mistakes (i.e., in school work, work, or other activities) | | |
| Have difficulty sustaining attention in tasks | | |
| Have difficulty listening when being spoke to (i.e., drift off, or daydream) | | |
| Have trouble following through on instructions or finishing tasks (not due to failure to understand the task) | | |
| Trouble organizing tasks and activities | | |
| Avoid, dislike, or are reluctant to engage in tasks that require sustained mental effort | | |
| Lose things necessary for tasks or activities | | |
| Easily distracted by extraneous stimuli | | |
| Forgetful in daily activities | | |
| Often fidget or squirm when required to sit | | |
| Feelings of restlessness | | |
| Difficulty engaging in leisure activities | | |
| Described as “on the go”, or feel like “being driven by a motor” | | |
| Talk excessively | | |
| Blurt out answers or interrupt other people | | |
| Trouble waiting your turn | | |

- Have you ever been tested for attention difficulties: yes _____ no _____

- Have you ever been diagnosed with an attention problem: yes _____ no _____
- If yes, please indicate at what age the diagnosis was made: _____
- Please describe the diagnosis that was made: _____
- Are you currently taking any medications that impact your attention: yes __ no _____
- Have you ever been diagnosed with any condition that may effect your performance in this study (i.e., learning disability, auditory condition, depression, etc.): yes _____
no _____
- If yes, please explain: _____

Thank-you for your participation in this study