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# Eye Tracking as a Behavioural Measure of Impulsivity

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**Eye Tracking as a Behavioural Measure of Impulsivity**

By

**Abirami R Kandasamy**

A Thesis  
Submitted to the Faculty of Graduate Studies  
through the Department of Psychology  
in Partial Fulfillment of the Requirements for  
the Degree of Master of Arts  
at the University of Windsor

Windsor, Ontario, Canada

2015

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September 16, 2015

## DECLARATION OF ORIGINALITY

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## ABSTRACT

Computerized testing provides insight into behaviours difficult to measure in traditional paper-pencil testing, such as impulsivity. Eye-tracking was recorded during the *Peabody Picture Vocabulary Test, Fourth Edition* digital stimulus book administration and output (saccadic speed, pupillary dilation, fixation duration, and reaction time) was used to predict impulsivity, as measured by the *Barratt Impulsiveness Scale - Eleventh Edition*. Demographic factors including ADHD diagnosis, age, gender, handedness, and SES were considered. Participants were 64 undergraduate students (50 women) at a medium-sized, ethnically diverse, university in southwestern Ontario. Hierarchical regressions showed greater impulsivity predicted lower PPVT-IV Standard Scores. Slower reaction-time and smaller pupil dilation predicted greater impulsivity, consistent with previous research. Impulsivity was related to ADHD diagnosis and gender, while PPVT-IV scores were associated with age and household income. Findings lend insight into the disparity between self-report and behavioural measures of impulsivity and provide objective measures to supplement behavioural observations during testing.

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## CHAPTER 1

### INTRODUCTION

Technological advances are changing the landscape of the practice of psychology. Online and computer administrations of psychological services have been growing in popularity over the past decade (Luxton, Pruitt, & Osenbach, 2014). The computerization of psychological assessments can allow for more accessible administration and ease of test scoring (Butcher, 2003). A recent trend has been to convert cognitive tests to computerized administration (PsychCorp, 2014). With advances in assessment procedures, such as the digitization of popular cognitive tests, there is an opportunity for adapting eye tracking tools to provide additional information during testing. Eye tracking is a technique that measures where an individual is looking at a given time and the sequence in which his/ her eyes shift from one location to another (Pool & Ball, 2006). The use of eye tracking has also become more prevalent in recent years, having been used to advance understanding of various types of cognition including memory, learning, and attention (Karatekin, 2007; van Gog & Schieter, 2010). Measurement of eye tracking during computerized test administration may provide objective, quantitative data to supplement traditional subjective test-taking behaviour observations.

Traditional assessment procedures consist of an examiner administering the test in accordance with standard procedure, while simultaneously observing the examinee's behaviours during testing. Observation of test-taking behaviour is an integral part of an evaluation (Sattler, 2014). Behavioural observation is crucial in determining whether an individual has performed to the best of his/her abilities during the test or whether there are any other factors undermining performance, such as impulsivity (Sattler, 2014).

Impulsivity can be characterized, succinctly, as lack of forethought (Barratt, 1994). A more comprehensive definition is provided below. Behaviours that occur during testing, which are evaluated subjectively by the test administrator, can result in missing or biased data and have the potential to paint an inaccurate picture of the individual's abilities (Von Elm, Altman, Egger, Gøtzsche, & Vandembroucke, 2007). Despite advances in test administration techniques, behavioural assessments remain mostly subjective, leaving untapped potential use for more objective approaches, such as using eye tracking technology.

The current study will use eye tracking equipment to determine whether impulsivity, a behaviour that may influence testing results, but is difficult to measure in traditional testing procedures, can be predicted and measured by tracking a participant's eye movements on a computerized test. Participants' engagement with the test in a digital form introduces a new dimension in assessment, particularly with regards to behavioural observations, that will need to be explored. In order to provide context for the present study, the role of behavioural observations in testing and impulsivity will be reviewed. With regards to impulsivity, definitions of impulsivity, the role of impulsivity in testing, self-report and behavioural measures of impulsivity, and using eye tracking to measure impulsivity will be considered.

### **Behavioural Observations**

Cognitive tests are used to assess aspects of a person's abilities empirically and can be used to screen for specific psychological disorders. These tests are interpreted in conjunction with behavioural observations in order to infer a more complete picture of an individual's functionality and abilities in vivo. Behavioural observations are therefore

necessary to obtain an accurate and thorough assessment (Sattler, 2014).

Validity can be defined as the extent to which an assessment instrument measures what it intends to measure (Kazdin, 2003). Assessment validity is crucial as the results are used to make predictions about an individual's abilities (Sattler, 2014). Although the validity of an assessment is multi-determined, behavioural data captured during assessment can be especially important for deciding overall assessment validity. For example, in addition to providing important qualitative and diagnostic information, behavioural cues related to mood (e.g., attitude toward test administrator), test difficulty (e.g., time spent on each item), and inattention (e.g., frequently glancing out the window during the assessment; Sattler, 2014) can offer clues regarding the validity of an individual's performance. Behavioural observations can refer to a wide range of formal (e.g., behavioural checklist) and informal (e.g., assessing client's personal hygiene) assessment techniques that provide supplementary information about the individual being tested (Lichtenberger, Mather, Kaufman, & Kaufman, 2004; Sattler, 2014). This information can aid in the collection of relevant, reliable, and valid information regarding the individual's performance (Sattler, 2014). Behavioural observations are also useful for hypothesis generation (i.e., about the individual's abilities or symptoms) when interpreting quantitative test scores (Sattler, 2014).

In psychological reports, behavioural observations are interpreted in conjunction with the quantitative data to provide a richer clinical assessment (Sattler, 2008).

Behaviour variables that examiners observe include attitudes of the examinee (toward testing, examiner, and self), sensory abilities (hearing and vision), motor abilities (gross, fine, and visual motor skills), level of engagement (attention and concentration), work

habits, expressive and receptive language, response style (e.g., effortful responding), motivation, tolerance for frustration, and persistence (Derefinko, Adams, Milich, Fillmore, Lorch, & Lynam, 2008; Sattler, 2008). Communication abilities such as eye contact, affect, self-confidence, and reactions to encouragement are also typically recorded (Sattler, 2008).

There are many advantages to having behavioural observations in assessment; however, there are limitations associated with these observations in the traditional form of testing. Examiners are responsible for administering test items using standard instructions and must simultaneously be aware of the examinee's behaviours during the assessment. Consequently, critical information may be lost due to divided attention (such as when the examiner looks away to record responses). Examiners are also subject to observer biases that may distort client information collected (Kazdin, 2003). Though examiners are trained to identify specific characteristics, these observations are typically unsystematic and there is a level of subjectivity inherently present in this method of observation (Elamin & Montori, 2012). Two different examiners may focus on and identify different behaviours occurring during testing. Examiners can be influenced by expectancy effects (subtle communication from the observer that influences the participant's behaviours in a specific way) and observation bias (when the examiner's attitudes or beliefs about the client influences the examiner's perspective), which may play a role in the examinee behaviours identified (Kazdin, 2003). These observer influences are threats to the external validity (i.e., the generalizability) of the data collected (Kazdin, 2003). Other influences on the individual's behaviour that are inherent to the testing situation include the presence of the examiner and reactivity to the

assessment (when test performance is altered because the individual is aware that his/her performance is being assessed; Kazdin, 2003).

Some behaviours that influence test validity are not as easily observed or quantified. Behaviours characteristic of disorders such as Attention Deficit Hyperactivity Disorder (ADHD; including inattention, hyperactivity, and impulsivity), are often measured and identified using disorder specific checklists. Identification of these behaviours is dependent on the test administrator observing the behaviours during the assessment. However some of these behaviours may vary in their physical manifestation and can be missed when relying on subjective measures (Von Elm et al., 2007). One such behaviour that is difficult to measure but may influence test performance is impulsivity (Förster, Higgins, & Bianco, 2003). Impulsivity can account for individual variation in test performance (Vigneau, Caissie, & Bors, 2006).

Variation in test performance can also be due to the medium in which the test is administered (i.e., paper vs. computer administration). In a study identifying key factors associated with test mode effect, the researchers found that gender, competitiveness, and computer familiarity were not related to performance differences, though content familiarity was (Clariana & Wallace, 2002). Pearson Education, Incorporated has recently released six speech and language assessments on Digital Stimulus Books, including the *Peabody Picture Vocabulary Test, Fourth Edition (PPVT-IV)*, which offers visual stimuli and content conducive to an investigation of behaviours that occur during testing on a computer (PsychCorp, 2014).

To summarize, behavioural observations are used in conjunction with cognitive tests to provide a richer clinical assessment. There are a variety of behavioural



observations that can inform the validity of an assessment, but they may be compromised by examiner error or oversight. Impulsivity is a behaviour that is difficult to observe reliably during traditional assessments. Variation in test performance on a computer vs. a paper-pencil task has not been found to be related to test modality. Therefore this study will integrate the technological advances in assessment, by using a standardized cognitive measure, with eye tracking technology to explore quantifying impulsive behaviours that have traditionally been measured using subjective methods. Participants will be provided with the same start-point (to ensure that all participants are exposed to the same content) and the ability to self-correct will be programmed.

### **Impulsivity**

Impulsivity is a multifaceted construct with no agreed upon definition.

Definitions of impulsivity in the research literature may refer to a trait that ranges from fluid to stable or from functional to debilitating. The lack of a singular definition makes it difficult to interpret the impulsivity literature due to methodological or conceptual differences used by different studies when defining impulsivity (Winstanley, Eagle, & Robbins, 2006). Impulsivity can broadly be defined as the tendency to act with less forethought than is characteristic of individuals with equal knowledge and ability (Winstanley et al., 2006). Specifically, it can be characterized as a predisposition toward unplanned, hasty reactions to stimuli (either external or internal) with little concern for subsequent negative consequences (Berlin & Hollander, 2008).

For instance, in testing situations, behavioural indicators of impulsivity include responding before the examiner completes asking the test question, having difficulty taking turns, and interrupting the examiner during testing (Sattler, 2014). The ability to

adjust cognition (decision-making) and behaviour in accordance with environmental demands plays a primary role in test settings, as it does in daily life (Diamantopoulou, Rydell, Thorell, & Bohlin, 2007; Stanford, Mathias, Dougherty, Lake, Anderson, & Patton, 2009). Elements of this ability are at the foundation of many of the definitions of impulsivity. The three most well established theories of impulsivity, as proposed by Eysenck, Dickman, and Barratt, are presented to further understand impulsivity and its relationship with test performance.

H. J. Eysenck (1967) was among the first to conceptualize impulsivity as a personality trait. Impulsivity was included as a subscale of extroversion (one of three-factors in Eysenck's theory of personality, which also included neuroticism and psychoticism) and was identified as risk taking, a lack of planning, and making up one's mind too quickly (Arce, & Santisteban, 2006). Eysenck further proposed that impulsivity consisted of three components: venturesomeness, impulsiveness, and empathy (Arce, & Santisteban, 2006; Eysenck & Eysenck, 1975). Though Eysenck's proposal characterizes impulsivity as pathological, the three components introduced varying types of impulsive behaviours that could manifest in the population.

Dickman's (1990) theory categorized impulsivity into functional and dysfunctional types. In this paradigm, individuals with functional impulsivity will use forethought only when doing so is optimal. On the other hand, individuals who demonstrate dysfunctional impulsivity will use less forethought than is typical for individuals of equal ability, which often has negative consequences (Claes et al., 2000; Evendeen, 1999). Dysfunctional impulsivity is characterized by error-prone information processing due to difficulty using a slower paced systematic approach under specific

circumstances (Dickman, 1990). The importance of Dickman's theory was introducing the idea that impulsivity could be present in the population in a non-pathological context (functional impulsivity).

Barratt's theory on impulsivity is among the more comprehensive approaches, integrating multiple perspectives including biological, psychological, behavioural, and social dimensions (Whiteside & Lynam, 2001). The most widely used measurement of impulsivity is the *Barratt Impulsiveness Scale (BIS)*; Barratt, 1956; Stanford et al., 2009). It is a self-report measure that was originally developed to demonstrate the relationship between anxiety and impulsivity in relation to psychomotor efficiency (Barratt, 1956; Stanford et al., 2009). Ernest S. Barratt hypothesized that anxiety and impulsivity are orthogonal constructs and that impulsivity may be related to a construct in the Hull-Spence Behaviour Theory called "oscillation". The Hull-Spence Behaviour Theory posits that discriminant learning occurs on a gradient of excitation and inhibition, which emphasizes incentive motivation (Spence, 1956). Oscillation is defined as momentary fluctuations in an individual's inclination to respond to a stimulus (Stanford et al., 2007; Spence, 1956). Barratt developed the *Barratt Impulsiveness Scale* to support his view on the distinction between impulsiveness and anxiety, as well as to demonstrate his secondary theory that impulsiveness is not a unidimensional construct (Barratt, 1956; Stanford et al., 2007).

Barratt defines impulsiveness as a multi-dimensional construct that consists of three subtraits including: cognitive impulsiveness (making quick decisions), motor impulsiveness (action without thought), and nonplanning impulsiveness (lack of forethought). These subtraits determined by a factor analysis of the *BIS-10*, can further

be broken down into attention, motor, self-control, cognitive complexity, perseverance, and cognitive instability (Barratt, 1994; Stanford et al., 2009). However, researchers have acknowledged that differentiating between types of impulsivity may not be useful since different types of impulsivity may result in similar outcomes or behaviours (Stanford et al., 2009). For the purposes of this study, impulsivity will be defined using Barratt's theory, which encompasses Eynseck's concept of varying levels of impulsivity and Dickman's conceptualization of functionality. As well, it integrates other influential factors characteristic of impulsivity such as the role of cognition and decision-making, which are relevant to testing.

**Impulsivity in Testing.** Decision-making, in the context of measuring impulsivity, is an individual's ability to weigh the consequence of immediate and future events and to delay gratification (Arce, & Santisteban, 2006). Decision-making is an integral part of testing (i.e., in multiple-choice test design) and can be influenced by impulsivity during testing. In a study measuring models of decision-making processes in animals, that underlie impulsive behaviours in humans, three underlying processes were found (Richards, Gancarz, & Hawk, 2011). Individuals with high impulsivity demonstrate three behaviours: decreased inhibitory control (poor response inhibition), delayed discounting (an insensitivity to delayed consequences) and lapses of attention (Corr, 2004; Richards et al., 2011; Winstanley et al., 2006).

By definition, individuals with high impulsivity, in accordance with Barratt's theory, demonstrate reduced response/ behavioural inhibition. They also show reduced punishment sensitivity and increased sensitivity to reward, as is measured in delayed reward discounting tasks (Stanford et al., 2009).

The first behaviour, decreased inhibitory control, is characterized by poor response inhibition. Inhibitory control is the ability to suppress non-productive behaviours or cognitive processes (Roberts, Fillmore, & Milich, 2011). The cued Go/No-Go task is a learning task designed to assess an individual's ability to inhibit designated responses. For example, after a trial has begun, the participant learns a "Go" Cue (a horizontal bar) or a "No-Go" Cue (a diagonal bar). Individuals then receive a point when responding (i.e., pressing a key) after a "Go" cue but will lose a point when failing to inhibit a response when given a "No-Go" Cue. The measure of impulsivity is the number of errors that indicate the individual's inability to inhibit the appropriate response (Fillmore, 2003; Newman, Widom, & Nathan, 1985).

Second, delayed discounting is when a reward loses value based on a delay in time (and can be characterized as insensitivity to delayed consequences; de Wit, Flory, Acheson, McCloskey, & Manuck, 2007). It manifests as an individual having a preference for smaller, immediate rewards rather than larger, delayed rewards, or, in effect, difficulty with delayed gratification (MacKillop, Amlung, Few, Ray, Sweet, & Munafò, 2012).

In a study that compared a delay discounting task and self-report questionnaires in 214 undergraduate students with a measure of cognitive distortions (Mobini, Grant, Kass, & Yeoman, 2007), delay discount rates were found to positively correlate with both functional and dysfunctional impulsivity and total level of impulsivity (as measured by *Barratt's Impulsiveness Scale – Eleventh Edition; BIS-11*), as well as nonplanning impulsivity (a subsection of the *BIS-11*). Participants who scored high on impulsivity were found to demonstrate delay discounting to a greater extent than those who scored

lower. Nonplanning impulsivity is indicative of an orientation to the present rather than future. As well, it was positively correlated with immediate reward selection and quick decision-making (Mobini et al., 2007).

Finally, with regard to attention and decision-making, studies show that individuals with high impulsivity have difficulties sustaining attention (i.e., are highly distractible) in an academic context (Levine, Waite, & Bowman, 2007). A study on school readiness and achievement demonstrated that children who can inhibit impulsive behaviours and pay attention are better able to take advantage of learning opportunities in the classroom and therefore more easily master reading and math concepts taught in school (Duncan et al., 2007). Multiple factors can influence the levels of impulsivity an individual demonstrates during testing and impulsivity can manifest in different ways. One way is in self-corrections during testing. In a review on attention, attention ratings, and cognitive assessments, individuals diagnosed with ADHD were found to demonstrate fewer self-corrections than do typically developed individuals (Boersma & Das, 2008). The challenge is capturing these various behaviours effectively and consistently through measurements of impulsivity.

Reaction Time and Impulsivity. Measurements of impulsivity, specifically behavioural measures, often demonstrate that individuals with high impulsivity show slower reaction times (Robinson et al., 2009). In a review of the underlying processes of impulsivity (in the context of drug use), it was found that attentional impulsivity is characterized by longer reaction times due to lapses in attention on the task (de Wit, 2009). This finding was further corroborated in a study looking at the association between laboratory measures of executive inhibitory control and self-reported impulsivity

(Enticott et al., 2006). On the stop-reaction time task, designed to measure a participant's ability to inhibit a prepotent motor response, longer reaction times were interpreted as indicating more impulsive responding (Logan, Schachar, & Tannock, 1997). Different subgroupings of self-report measures (e.g., motor and attentional impulsivity) were found to relate to different behavioural measures of impulsivity (Enticott et al., 2006).

**Measuring Impulsivity.** Impulsivity is most frequently measured through self-report questionnaires that have been normed on typically developed and clinical populations (Stanford et al., 2009). However, most of these measures have been developed based on different conceptualizations of impulsivity and may therefore vary fundamentally (Winstanley et al., 2006). Self-report measures of impulsivity typically ask individuals to evaluate their endorsement of example scenarios related to impulsivity (e.g., risk-taking or the decision-making process; Vigil-Colet, 2011). Behavioural measurements of impulsivity are tasks completed in laboratory settings that measure inhibitory actions such as inability to wait, inability to withhold a response, and insensitivity to delay consequences (Richards et al., 2011).

Studies demonstrate that behavioural measurements of impulsivity do not align well with self-report measures such as the *BIS-11* (Stanford et al., 2009). It has been hypothesized that this discrepancy may be due to the fact that self-report measures tap into stable personality traits while behavioural measures are state-dependent, isolated in time, and may be measuring more than just impulsivity (Stanford et al., 2009). It has also been suggested that self-report measures may not capture the dimensions of impulsivity being measured in decision-making behavioural tasks (Vigil-Colet, 2011).

As mentioned, the most widely used measurement of impulsivity is the *Barratt*

*Impulsiveness Scale (BIS-11)*; Stanford et al., 2009). The *BIS-11* has high convergent validity with other self-report measures of impulsivity but not with previously established behavioural measures including continuous performance tests (which measure sustained and selective attention), stop tasks, and delay-discounting measures (delay of gratification tasks; Shalev, Ben-Simon, Mevorach, Cohen & Tsal, 2011; Stanford et al., 2009).

In a study comparing the *BIS-11* (as well as two other self-report tests) to four behavioural measures: two behavioral inhibition tasks (*Stop Task* and cued *Go/No-Go Task*), a delay discounting task, and a risk-taking task (*Balloon Analog Risk-Taking Task*), it was found that self-report did not correlate with the behavioural measures of impulsivity (Reynolds, Ortengren, Richards, & de Wit, 2006). Using a principle component analysis, Reynolds et al., (2006) found that behavioural measures of impulsivity could be divided into “impulsive disinhibition” (*Stop Task* and *Go/No-Go Task*) and “impulsive decision-making” (*Delay-Discounting Task* and *Balloon Analog Risk-Taking Task*).

Impulsive disinhibition refers to tasks that measure inhibition (Reynolds et al., 2006). The stop task, as described above, measures this by assessing the participants’ ability to inhibit a prepotent motor response (Logan, Schachar, & Tannock, 1997) while the Go/No-Go task measures it by the participants’ ability to inhibit inappropriate responses (Newman, Widom, & Nathan, 1985). Impulsive decision-making requires the participant to evaluate different outcome consequences based on a decision (Reynolds et al., 2006). The Delay Discounting task measures the relative value of immediate and delayed rewards (Richards, Zhang, Mitchell, & de Wit, 1999). The *Balloon Analogue Risk-Taking Task (BART)*; International Society for Research on Impulsivity, 2014) is a



measure of risk-taking in which participants are given the option of pumping up a balloon, and for each pump the participant receives a (fictional) monetary amount or the option to terminate the trial and keep the accumulated monetary amount. For each balloon task, after a varying number of pumps, the balloon may explode and the accumulated monetary amount will not be added to a grand total (Lejuez et al., 2002). Participants who produce a greater number of pumps and explosions are considered more impulsive.

Impulsive decision-making is of particular relevance to testing. Typically when the *BART* is used to measure impulsivity, participants fill out a self-report questionnaire which divides them into two groups of high vs. low impulsive which are then compared on their *BART* output (Hunt et al., 2005; Vigil-Colet, 2007). The problem is that high and low impulsive groups do not demonstrate significant differences when measured in this way (LeJuez et al., 2002).

Vigil-Colet (2007) studied impulsivity and decision-making on the *BART* by applying Dickman's model of functionality in impulsivity. Results of his study demonstrated that neither dysfunctional impulsivity (as measured by Dickman's Impulsivity Inventory) nor "narrow impulsivity" (as measured by Eysenck's Impulsivity Inventory) are related to the decision process in the *BART*. However, he found that functional impulsivity was related to an impulsive decision-making style in low risk decision-making conditions (Vigil-Colet, 2007). This study demonstrates that behavioural measures of impulsivity reflect facets of impulsivity related to decision-making. Vigil-Colet (2007) acknowledged that while LeJuez and colleagues (2002) found convergent validity between scores on the *BART* and *Barratt Impulsiveness Scale-*

10, other studies have failed to replicate this finding (2007). Since the convergent validity of behavioural and self-report measures of impulsivity is equivocal, the methodology used in the present study will circumvent this problem by independently predicting impulsivity from the eye tracker output, using this data as a behavioural measure of impulsivity. Inhibitory control of eye movement has been shown to be negatively related to self-reported impulsivity (Roberts et al., 2011).

Inhibitory control tasks (as quantified by behavioural measures of impulsivity) have been examined in relation to facets of self-reported impulsivity (as measured by self-report instruments) using a manual, cued Go/No-Go task and an oculomotor response inhibition task, a visual stopping task (Roberts et al., 2011). The researchers suggested that inconsistent findings between self-reported and behavioural measures of impulsivity likely reflect methodological issues relating to the measure of impulsivity because the total score of self-report measures captures varying facets of impulsivity. They found that oculomotor inhibitory control (i.e., keeping the eyes from looking at a certain part of an image), but not manual control (i.e., purposefully controlling where the eye is looking) is related to self-reported impulsivity. Though the mechanism of the success of oculomotor tasks in relation to impulsivity is unknown, it suggests that eye tracking may be key for understanding the disparity between these two types of tests (Roberts et al., 2011). Therefore eye tracking will be used in the present study to bridge the gap between self-report and behavioural measures of impulsivity.

**Eye tracking and Impulsivity.** Eye tracking is a non-invasive, video-based, measurement technique that can be used for insight into cognitive processes such as visual-spatial attention, memory, and motivation that are otherwise difficult to qualify

(Karatekin, 2007). A large body of research exists that details factors related to eye movement and its relation to specific cognitive and motor processes (Karatekin, 2007). Multiple studies have demonstrated the effectiveness of eye tracking and, due to advances in technology, the use of eye trackers is becoming more widespread (Bohme, Meyer, Martinetz, & Barth, 2006). Eye tracking measurements have contributed to understanding theoretical models of different types of cognition (Salvucci & Goldberg, 2000). The aim of the present study is to do the same with impulsivity.

Eye tracking studies analyzing scene perceptions (within the parameters of the edges of the computer screen) have operationally quantified prosaccadic movements and speed, pupillary dilation, as well as fixation duration (Hartnegg & Fischer, 2002). These variables will be measured in this study.

*Saccadic Movements.* Saccades are eye movements that occur to bring objects within sharp central vision (i.e., foveal vision). Saccadic movements from one object to another are related to a shift in visual-spatial attention to these objects (Martinez-Conde, Macknik, & Hubel, 2004). The main measures that an eye tracker would extract from saccadic eye movements are duration, peak velocity, amplitude, and latency to initiate the saccade (i.e., the time it takes for saccadic movement to begin). People who are more impulsive tend to have faster eye movement (saccades) when scanning a page (Choi, Vaswani, & Shadmehr, 2014).

In a review on eye tracking in relation to atypical development it was found that individuals who are considered highly impulsive (group diagnosed with ADHD) made premature saccades and fewer corrective saccades on reading tasks than did a matched group (Karatekin, 2007). As well, these individuals made more errors on antisaccadic

tasks (tasks in which they are to inhibit eye movements). Such errors are characteristic of response initiation impulsivity (responding prior to processing; Dougherty & Marsh, 2003; Karatekin, 2007). These are behaviours that can be expected from individuals who score high on in impulsivity.

*Pupillary Dilation.* The eyes respond to cognitive and affective arousing stimuli through pupil dilation, which can reveal information about a person's current mental state (Marshall, 2007). Pupillary dilation can be useful for testing theories founded in physiology since research suggests that dilation is dependent on neural control (rather than autonomic function). Dilation is quite sensitive to working memory load and has been correlated with greater task difficulty (Just, Carpenter, & Miyake, 2003). Eye tracking and pupillometry have been used in previous research to understand the decision process, through measures of "eye gaze dwell" (fixations), "drift rate" (speed), and "pupil dilation" (Cavanagh et al., 2014). Greater pupil dilation was found to relate to an increased "decision threshold", indicative of slower reaction time and greater accuracy (Cavanagh et al., 2014). This pattern of response is indicative of complex decision-making that requires weighing options.

*Fixation Duration.* In the general population, fixation duration increases and saccadic amplitude decreases when task difficulty is greater (Karatekin, 2007). In studies analyzing eye movements when focusing on a stationary image, the main measures used include: location (i.e. area of interest on the image) and duration (of fixations). A fixation point is a point on the image where the individual's attention is focused for longer than random scanning patterns. Areas of interest are defined locations of the stimuli on which it is expected that participants will fixate. These varying measurements are useful for

gauging an individual's attention and engagement with digital stimuli. Time spent on each stimulus (fixation duration) and number of fixations is expected to be longer in individuals who are highly impulsive because of time lapses in attention during the task (de Wit, 2009).

Time plays an important role when evaluating impulsivity since decisions made with little forethought means less time spent considering outcomes associated with choices. Studies demonstrate that highly impulsive individuals have an altered perception of time in which they subjectively experience time delay as longer than individuals who choose delayed reward (Berlin, Rolls, & Kischka, 2004; Wittmann & Paulus, 2008). High impulsive individuals also overestimate durations in time-estimation tasks (Berlin et al., 2004). This tendency may influence fixation duration and number of fixation points as measured by the eye tracker. As well, reaction time is anticipated to be slower (de Wit, 2009)

**Demographic Variables and Impulsivity.** Quantifying the level of impulsivity, reaction time, and receptive vocabulary performance can be influenced by demographic factors such as a diagnosis of ADHD, age, gender, handedness, socioeconomic status (SES), and ethnicity (Dunn & Dunn, 2007; Upton et al., 2011; de Wit, 2009).

*Attention Deficit Hyperactivity Disorder (ADHD).* Impulsivity is a component behaviour of multiple mental health illnesses, prominently ADHD (Winstanley, Eagle, & Robbins, 2006). A review on reaction time variability in ADHD concluded that individuals with ADHD experience an increase in reaction time due to attentional lapses (Tamm et al., 2012).

*Age.* Research has shown that reaction time in “normal” adults who completed the *BIS-11* and a timed reaction task is more variable in people with greater *BIS-11* Motor Subscale scores (Enticott et al., 2006). Reaction times have been found to slow and become more variable with age (Der & Deary, 2006). Age can influence standard scores on cognitive tests and receptive vocabulary (Dunn & Dunn, 2007).

*Gender.* In a meta-analysis on sex differences in impulsivity, sex differences were not found in delay discounting or executive functioning tasks (Cross et al., 2011). However, high impulsive males were found to exhibit higher sensation seeking behaviours than females (Cross et al., 2011). In choice reaction time tasks, over several trials, women were found to be initially slower than men but eventually became faster than men across the testing block, ultimately resulting in similar overall reaction times (Reimers & Maylor, 2006). In a study on gender differences in adult word learning, gender was found to effect reaction time variability, trial-to-trial language tasks, and differences in word learning (Kaushanskaya et al., 2011).

*Handedness.* Handedness has not been found to predict ADHD (Ghanizadeh, 2010), though research has shown that handedness can influence population levels of impulsivity (Wright, Hardie, & Wilson, 2009). Left-handed females have been found to show more inhibition (Wright et al., 2009). A review of reaction time showed that both right and left-handed people were equally fast when using a mouse (Kosinski, 2008; Peters & Ivanoff, 1999) and computer task difficulty was not related to reaction time (Bryden, 2002; Kosinski, 2008). Handedness has not been found to relate to test performance (Bryden & Roy, 2005; Van der Elst, Van Boxtel, Van Breukelen, & Jolles, 2006).

*Socioeconomic status.* Socioeconomic status (SES) can be identified using individual-level (maternal level of education) and community-level (neighbourhood income) measures. It can influence multiple domains of an individual's life and outcome (Luo, Wilkins, & Kramer, 2006). In the context of gambling, high SES has not been found to predict impulsive behaviours while research has demonstrated that low SES predicts impulsive behaviours (Auger, Lo, Cantinotti, & O'Loughlin, 2010). SES has not been found to relate to reaction time (Hackman & Farah, 2009). SES has been shown to be related to language development, specifically individuals with greater SES have been found to have greater lexical development (Hoff & Tian, 2005). For the purposes of this study, SES will be measured on an individual-level using maternal education and total household income will be used to infer community-level SES.

*Ethnicity.* Ethnicity and cultural identity is an important facet of an individual. Impulsivity as measured by the impulsivity subscale of the *Adult Attention Deficit Disorder Evaluation Scales* (McCarney & Anderson, 1996) has not been found to differ based on ethnicity (Lorber & Slep, 2011). Literature on ethnicity and reaction time is sparse. However, a study on reaction time distribution of neuropsychological performance in an ADHD sample found that children with ADHD demonstrated slower and more variable reaction times when matched for gender age, and ethnicity (Hervey et al., 2006).

Due to the influences these demographic variables have on impulsive behaviours, reaction times, and performance on vocabulary or testing, ADHD, age, gender, handedness, maternal education, and household income will be collected from

participants. As well, English as a first language will be a requirement to circumvent differences due to language exposure. Number of languages spoken will also be noted.

To review, impulsivity is a multifaceted construct that can manifest in varying levels and can range from functional to dysfunctional. Cognitive impulsivity (as occurs in testing) is particularly related to decision-making. Self-report measures and behavioural measures of impulsivity do not always align. Eye tracking will be adapted to a cognitive test to predict relevant components of impulsivity and to provide information regarding the disparity between self-report and behavioural measures of impulsivity. As well, the relationship between impulsivity and performance on a cognitive measure will be explored.

### **The Present Study**

In the present study, eye tracking was used to extract new behavioural information (the relationship between impulsivity and decision-making during testing) that is not being measured empirically in traditional administration of cognitive tests. Specifically, a computerized cognitive test that has a divided visual array located in a repetitive and predictable location with escalating difficulty (which increases effort and cognitive load) was used. Eye tracking output was adapted to a cognitive test to measure important and relevant components of impulsivity including saccadic speed, pupillary dilation, fixation duration, reaction time, and cognitive test performance. Independent variables are listed in Table 1. These variables were used to predict impulsivity as measured by a self-report questionnaire and to provide insight into the disparity between self-report and behavioural measures of impulsivity. Demographic factors such as ADHD diagnosis, age, gender, handedness, and SES were considered when measuring



Table 1.

*Independent Variables (Eye tracker Behavioural Output)*

Hypothesis	Independent Variables
1a	Average speed of saccadic movements
1b	Average time before saccadic movements begin
2	Ratio of time when pupils are dilated: not dilated
3a	Average fixation duration per quadrant
3b	Number of fixations per stimulus
4a	Overall Time
4b	Average Time per Stimulus
5a	Cognitive Test Standard Score
5b	Percent Correct on the Cognitive Test
5c	Number of Self-Corrections

impulsivity. To summarize, the present study used eye tracker output and reaction time to predict impulsivity and to explore the relationship between impulsivity and performance on assessments.

**Hypotheses.** It was anticipated that high self-reported impulsivity would demonstrate a relationship with the eye tracker output. Eye tracking output and impulsivity scores were then used to predict the performance on a cognitive test to demonstrate the relationship between impulsivity and test performance. As mentioned, an oculomotor response inhibition task was found to be related to self-reported impulsivity (Roberts et al., 2011), therefore it was anticipated that the eye tracker would be able to capture self-reported impulsivity.

**Hypothesis 1: Saccadic eye movements.**

*1a. Speed.* It was anticipated that individuals with higher impulsivity scores would demonstrate a higher average speed of saccadic movements overall, over and above ADHD, age, gender, handedness, and SES, as determined by household income and maternal education (Choi et al., 2014; Karatekin, 2007). Individual differences in processing speed were considered when interpreting results.

*1b. Latency to initiate.* It was anticipated that individuals with higher impulsivity scores would demonstrate shorter average latency to initiate saccadic movements (Berlin et al., 2004; Dougherty & Marsh, 2003; Wittman & Paulus, 2008), over and above ADHD, age, gender, handedness, and SES, as determined by household income and maternal education.

**Hypothesis 2: Pupillary dilation.** It was anticipated that individuals with higher impulsivity scores would show a greater ratio of pupil dilation, as measured by maximum

vs. minimum pupil diameter due to greater arousal from attentional demands while the body is stationary (Cavanagh et al., 2014, de Witt, 2009; Just et al., 2003), over and above ADHD, age, gender, handedness, and SES (as determined by household income and maternal education).

**Hypothesis 3: Fixation points.**

*3a. Fixation duration.* It was anticipated that individuals with higher impulsivity scores would have greater fixation duration per quadrant, since they would respond slower due to attentional lapses (de Wit, 2009), over and above ADHD, age, gender, handedness, and SES (as determined by household income and maternal education).

*3b. Number of fixations per stimulus.* It was anticipated that individuals with higher impulsivity scores would have a higher number of fixations, or transitions per quadrant, per stimulus (Barry et al., 2005; de Wit, 2009; Dougherty & Marsh, 2003), over and above ADHD, age, gender, handedness, and SES (as determined by household income and maternal education).

**Hypothesis 4: Reaction time.**

*4a. Adjusted overall time.* It was anticipated that individuals with higher impulsivity scores would demonstrate a longer overall time of testing (de Wit, 2009; Enticott et al., 2006; Robinson et al., 2009), over and above ADHD, age, gender, handedness, and SES (as determined by household income and maternal education).

*4b. Average time per stimulus.* It was anticipated that individuals with higher impulsivity scores would demonstrate a longer amount of time per stimulus (de Wit, 2009; Enticott et al., 2006; Robinson et al., 2009), over and above ADHD, age, gender, handedness, and SES (as determined by household income and maternal education).

Individual variation in number of stimuli was addressed through taking the average time per stimulus.

**Hypothesis 5: Cognitive Test Performance.**

*5a. Cognitive Test Standard Score.* It was anticipated that individuals with higher impulsivity scores, as measured by the total *BIS-11* score and three *BIS-11* Subscales (Attention, Motor, and Nonplanning), would demonstrate lower *PPVT-IV* Standard Score (Förster et al., 2003; Vigneaux et al., 2006), over and above ADHD, age, gender, handedness, and SES (as determined by household income and maternal education). Individual variation in number of stimuli was addressed through the use of standard scores.

*5b. Percent Correct on the Cognitive Test.* It was anticipated that individuals with higher impulsivity scores would demonstrate lower percentages of correct responses (Förster et al., 2003; Vigneaux et al., 2006), over and above ADHD, age, gender, handedness, and SES (as determined by household income and maternal education). Individual variation in number of stimuli was addressed through the use of a percentage of correct scores.

*5c. Number of Self-Corrections.* It was anticipated that individuals with higher impulsivity scores would demonstrate a higher number of self-corrections (Boersma & Das, 2008; Ibarrola, 2009), over and above ADHD, age, gender, handedness, and SES (as determined by household income and maternal education).

## CHAPTER 2

### METHODS

#### **Participants**

The sample consisted of 64 undergraduate students (50 women, 14 men) at a medium-sized, ethnically diverse, Canadian university (student population greater than 15 000) in a multicultural city (population 200,000). Participants all identified English as their first language. The majority (78%) of participants were monolingual, 17% were bilingual, and 5% were trilingual. The sample included 13% first-year, 25% second-year, 36% third-year, and 26% fourth, or final year students ages 18 to 39 years ( $M_{64} = 23.06$ ,  $SD = 6.16$ ). Most participants (96%) received a high school diploma as their highest level of education received prior to beginning their undergraduate degree; 4% received a college diploma prior to beginning their undergraduate degree. Most participants were right-handed (94%) and the remaining participants (6%) were left-handed. The majority of participants (58%) reported no visual impairments, while 42% had visual impairments for which they wore corrective lenses. Participants were screened for hearing impairments; only one participant identified as being hearing impaired and could not complete the study. As well, the majority of participants (86%) reported no diagnosis of mental health difficulties, though 5% were diagnosed with Attention Deficit Hyperactivity Disorder and 9% were diagnosed with other mental health disorders (i.e., anxiety, depression, and bipolar disorder). The majority of participants identified as Caucasian (61%), followed by Black (13%), Arab (9%), South Asian (5%), and East Asian (2%); 10% of participants were Biracial. In terms of combined annual household income, 33% of participants were from a household with an income greater than \$100

000 (upper middle class), 42% were from \$50 000-100 000 (middle class), and 25% were from less than \$40 000 (“poorest 20% of Canada”; Hodges & Brown, 2015). Program of study, maternal and paternal income and education are listed in Tables 2a, and 2b.

**Participant Recruitment.** A power analysis was conducted to estimate sample size for linear multiple regression, anticipating an effect size of 0.5 with a power of 0.8. This analysis suggested that approximately 35 participants be recruited for eight independent variables. In order to maximize statistical effectiveness and account for potential participant errors or incompletions, additional participants were recruited. All participants were recruited from the University of Windsor’s Participant Pool (Appendix A). They were screened for the item “English as a first language”, prior to participating in the study. Participants provided REB-approved informed consent. After participation in the study, participants were awarded one participant pool point for one hour of participation.

## **Measures**

The measures that were used in this study were the *Barratt Impulsiveness Scale – Eleventh Edition (BIS-11)*; Stanford et al., 2009) and the *Peabody Picture Vocabulary Test – Fourth Edition (PPVT-IV)*; Dunn & Dunn, 2007). As well, relevant demographic information was collected.

**The Barratt Impulsiveness Scale – Eleventh Edition (BIS-11).** The *Barratt Impulsiveness Scale (BIS-11)*; Stanford et al., 2009) has 30 items measured on a 4-point Likert scale. These items were developed from a theoretical framework to measure impulsiveness in a nonunidimensional framework that was orthogonal to anxiety. Individuals are asked to report on how they would act/think in different scenarios. Each

Table 2a

*Program of Study*

	% of Participants
Psychology	31
Double Major Including Psychology	16
Biology	11
Human Kinetics	8
Behaviour, Cognition, and Neuroscience	8
Social Work	5
Nursing	5
Sociology	3
Drama	3
Disabilities Studies	3
Other	3

N=64

Table 2b

*Maternal and Paternal Income and Highest Level of Education*

	% Maternal	% Paternal
Income (\$)		
<5000	13	-
5-9 999	8	-
10-19 999	11	-
20-29 999	13	5
30-39 999	16	3
40-49 999	3	-
50-59 999	9	11
60-69 999	8	6
70-79 999	3	14
80-89 999	5	13
90-99 999	2	6
>100 000	3	30
Other	6	13
Highest Level of Education		
Less than High School	5	14
High School	25	13
College	28	31
Undergraduate Degree	31	28
Masters	9	8
PhD	3	-
Other	-	6

N=64



question is rated on a scale from 1 to 4, for which 1 is rarely/never and 4 is almost always/always. The scale measures three subtraits including: cognitive/attentional impulsiveness (making quick decisions), motor impulsiveness (action without thought), and nonplanning impulsiveness (lack of forethought; Stanford et al., 2009). Revised versions of the *BIS* were redesigned to measure these subtraits that Barratt theorized impulsivity was comprised of (Stanford et al., 2009). Scale items can be further broken down into measurements of attention, motor, self-control, cognitive complexity, perseverance, and cognitive instability, which were identified through a factor analysis (Stanford et al., 2009). Test-retest reliability of the *BIS-11* is 0.83 and internal consistency is  $\alpha=0.83$  (Reid, 2013). Internal consistence of the *BIS-11* Attention Subscale is  $\alpha=0.74$ , Motor Subscale is  $\alpha=0.59$ , and Nonplanning Subscale is  $\alpha=0.72$  (Stanford et al., 2009). The *BIS-11* demonstrates high convergent validity with other self-report measures of impulsivity including Eysenck's Impulsiveness Scale (Patton & Stanford, 1995; Stanford et al., 2009). Higher scores on the *BIS-11* indicate higher levels of impulsivity; with 72 as the clinical cutoff for "high impulsivity" (Stanford et al., 2009). This test is publicly available; therefore, no permissions were sought for its use.

#### **The Peabody Picture Vocabulary Test – Fourth Edition (PPVT-IV)**

The *Peabody Picture Vocabulary Test, Fourth Edition (PPVT-IV)*; norm referenced from ages 2:6-90 years; PsychCorp, 2014) is a widely used 228-item test that measures receptive (hearing) vocabulary knowledge (breadth and precision) and can provide insight into many other avenues of functioning. Research shows that bilingual individuals perform lower than monolingual peers when tested on the *PPVT-III* with bilingual individuals who were born outside of the United States of America (USA) but

arrived in the USA at a younger age, performing better than those who were born outside of the USA but arrived at an older age (Portocarrero, Burrigh, & Donovan, 2007). For this reason, the participant criterion of English as a first language will be included.

For the purposes of this study, a start point of stimulus #145 was used, meaning that a maximum of 83 stimuli were presented to each participant. This start point is for ages 17+ (Dunn & Dunn, 2007). It was assumed that participants aged 19+ can pass items #145 until the standardized start point for 19+, which is #157. To maintain a standardized procedure, all participants began at the stimulus #145, regardless of age. Since participants were from a university population, it was assumed that reverse criteria would not be necessary. Prior to the study, it was determined that if all 8 items from #145-#157 are failed, typical administration of the *PPVT-IV* would require a reversal to the previous age group (Dunn & Dunn, 2007). However, for the purposes of the study, eight consecutive incorrect responses signified the ending of all participants' testing. The stimulus presented contained four quadrants with different images in each quadrant. The number of cards completed was important because the minimum number of cards determined which cards were analyzed. The examinee is instructed to identify the corresponding image to a given stimulus word. Once discontinue criterion has been met or the examinee completes the test, a raw score of number of correct responses is obtained. The raw scores is converted to a standard *T-Score* based on age. Percentiles and confidence intervals are also calculated. The average level of receptive vocabulary is a *T-Score* in the range of 85-115 (American norms).

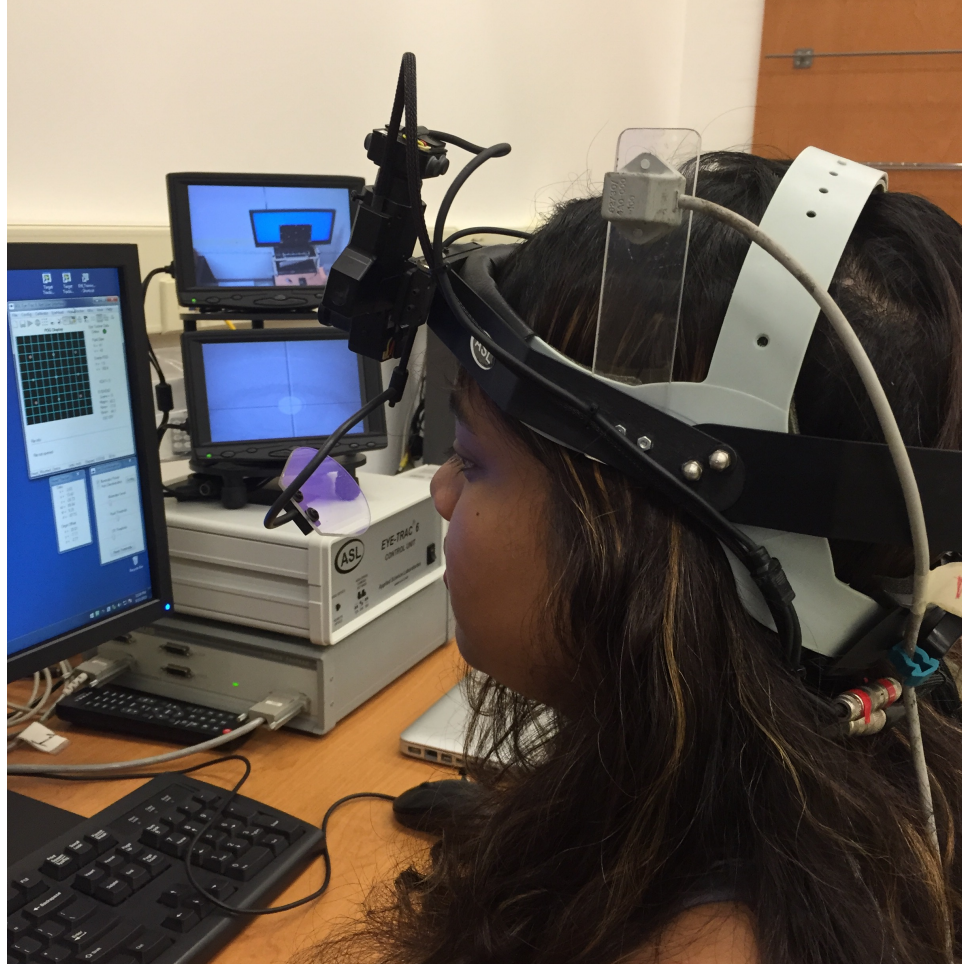
The *PPVT-IV* is known to have high reliability, low cultural bias, it is informative for special populations, and it is an efficient and accurate estimate of an individual's

intelligence quotient (Dunn & Dunn, 2007; Haitana, Pitama, & Rucklidge, 2010).

The *PPVT-IV* is a preferred test among psychologists because of its ease of administration: it is a 15-minute evaluation that requires little instruction (Dunn & Dunn, 2007). The test content covers a range of receptive vocabulary levels and content areas (e.g., actions, tools, and vegetables). Test-retest reliability of the *PPVT-IV* is 0.93 and it is considered a valid test of IQ and vocabulary knowledge (Dunn & Dunn, 2007).

This test was chosen because it is a psychometrically sound, efficiently administered test that consists of visual stimuli conducive to an investigation of measuring impulsivity during testing using an eye tracker. In this test, a stimulus with four images is presented and the participant must identify which image corresponds with a given word. Use of this test in a research context was approved through Pearson Incorporated.

**Applied Sciences Laboratory Eye Tracker.** The Applied Sciences Laboratory's Eye-Trac 6 utilizes a head-mounted optic that keeps an individual stationary as his/her eye movements are tracked on the computer screen (Figure 1). The Eye-Trac 6 .NET User Interface program is a system that is connected to the head-mounted eye monitor and measures where the eye is focused on a computer screen. Prior to the study, a custom eye tracking program was created by Don Clarke, a Research Technician in the Human Kinetics Department of the University of Windsor, in which the digital stimulus book of the *PPVT-IV* was integrated. Since the stimuli used in the *PPVT-IV* are divided into four quadrants, the screen was segmented into four quadrants as well. All of the stimuli data (maximum 83 stimuli) were recorded, per person. In between each stimulus, a central fixation point was presented in order to differentiate between the eye tracking outputs per stimulus. Participants typed their response (1, 2, 3, or 4) of which the quadrant they identified as the corresponding response to the stimulus word, which then



*Figure 1.* Eye-Trac 6 computer and head-mounted eye monitor

([http://www.asleyetracking.com/Site/Portals/0/DSC\\_0065%20\(rotated\).JPG](http://www.asleyetracking.com/Site/Portals/0/DSC_0065%20(rotated).JPG))

introduced the next stimuli. The stimuli words were recorded ahead of time and were prompted by the numerical response key pressed. The image and the word were presented at the same time. The difference from traditional administration of the *PPVT-IV* is that each stimulus word was repeated after a 0.5 second delay for every word, whereas in traditional administration, the examiner may repeat the word one time only if the examinee requests it. This procedure was used to maintain standard administration across participants. Another deviation from traditional administration was that participants keyed in their responses rather than orating or pointing to an answer. Programming allowed participants to self-correct, as long as they responded prior to the next stimulus appearing, which occurred after a 2-second delay. The eye tracker output included saccadic movement and speed, pupillary dilation, fixation duration, and fixation frequency. The program created for the eye tracker outputs the reaction time and self-correction data as well as raw *PPVT-IV* scores. Standard *PPVT-IV* scores were hand-calculated using the standardized *PPVT-IV* Administrator's manual. The eye tracker output saccadic movements and speed, pupillary dilation, and fixation durations. Specifically, the eye tracker output numeric data (i.e. temporal and distance measures) that was used to calculate saccadic speed and provided saccadic latency (time before saccadic movements begin). It provided information indicating at which temporal points the participant experienced pupillary dilation and the diameter of dilation. The eye tracker's numeric output was used to calculate the duration of fixation points. Output also includes fixations per stimulus (i.e. the number of fixations made when looking at a stimulus card).

The demographic form (Appendix B) contained information about age, gender,

handedness, highest level of education, year of study, program of study, physical impairments (including visual or hearing), diagnoses of mental health difficulties (such as ADHD), maternal and paternal income, level of education, and occupation, culture/ethnicity, first language spoken in the home, as well as other spoken languages. Age, gender, handedness, level of education, culture/ethnicity and program of study were identified as influential on *PPVT-IV* performance and impulsivity (Cross et al., 2011; Dunn & Dunn, 2007; Enticott et al., 2006; Wright et al., 2009). Maternal and paternal income, level of education, and occupation are measures of SES, which are relevant to the *PPVT-IV* performance and impulsivity (Luo et al., 2006). Mental health diagnoses are relevant because impulsivity is often a symptom of ADHD and therefore it is a factor that must be controlled for (Winstanley et al., 2006). First language spoken in the home as well as other spoken languages offers insight into vocabulary abilities, relevant to the *PPVT-IV* because it is a vocabulary test (Dunn & Dunn, 2007; Portocarrero et al., 2007). For this reason, participation was restricted to speakers of English as their first language. Vision and hearing were important factors that were screened for because they were necessary abilities to complete the digital stimulus book of the *PPVT-IV*. Specifically, participants looked at a screen while the stimulus word played from a speaker located behind them.

### **Procedure**

Undergraduate students from the University of Windsor who were recruited from the participant pool and passed the screener question (English as a first language; Appendix A) were brought into the Motor Lab in the Human Kinetics Department for a one-hour testing session. Participants were briefed on the study and consented to the

conditions of withdrawal before proceeding (Appendix C). They were then provided a standard demographic information form (Appendix B), followed by a calibration to the Eye-Trac 6 head-mounted optic. Calibration required the participant to be fitted to the head mount of the eye tracker (weight=0.75 lbs.) and for the left eye to look at nine focal test points on the test computer screen while pressing a button on a mouse (Figure 2). The calibration procedure ensured that participants' eye-movements could be tracked using the eye tracker. Tracking can only take place if there is a solid pupil line and cornea line (the difference is used to calculate where the eye is looking). Pupil dilation was also measured. If either line flickered or went missing, the eye tracking data became void. Once the calibration was completed and the participants passed the test screen, they received the modified instructions for the administration of the *PPVT-IV* (i.e., to press the button corresponding to their answer) and to focus on the central fixation point in between cards. Participants were told that the stimulus word would be played from the speaker behind them. The buttons were on a numeric keypad that had labels corresponding to the quadrant numbers (Figure 3). Because the *PPVT-IV* is a relatively short test to administer (Overall time  $M_{64}=9.44\text{min}$ ,  $SD=0.66$ ) fatigue was not an issue.

Once the *PPVT-IV* was completed, the headgear was removed and participants completed the *BIS-11* (a paper test). Finally, participants were debriefed on the study (Appendix D) and received a letter of information with researcher contact information, details of the study, and rights of the participant (Appendix E).

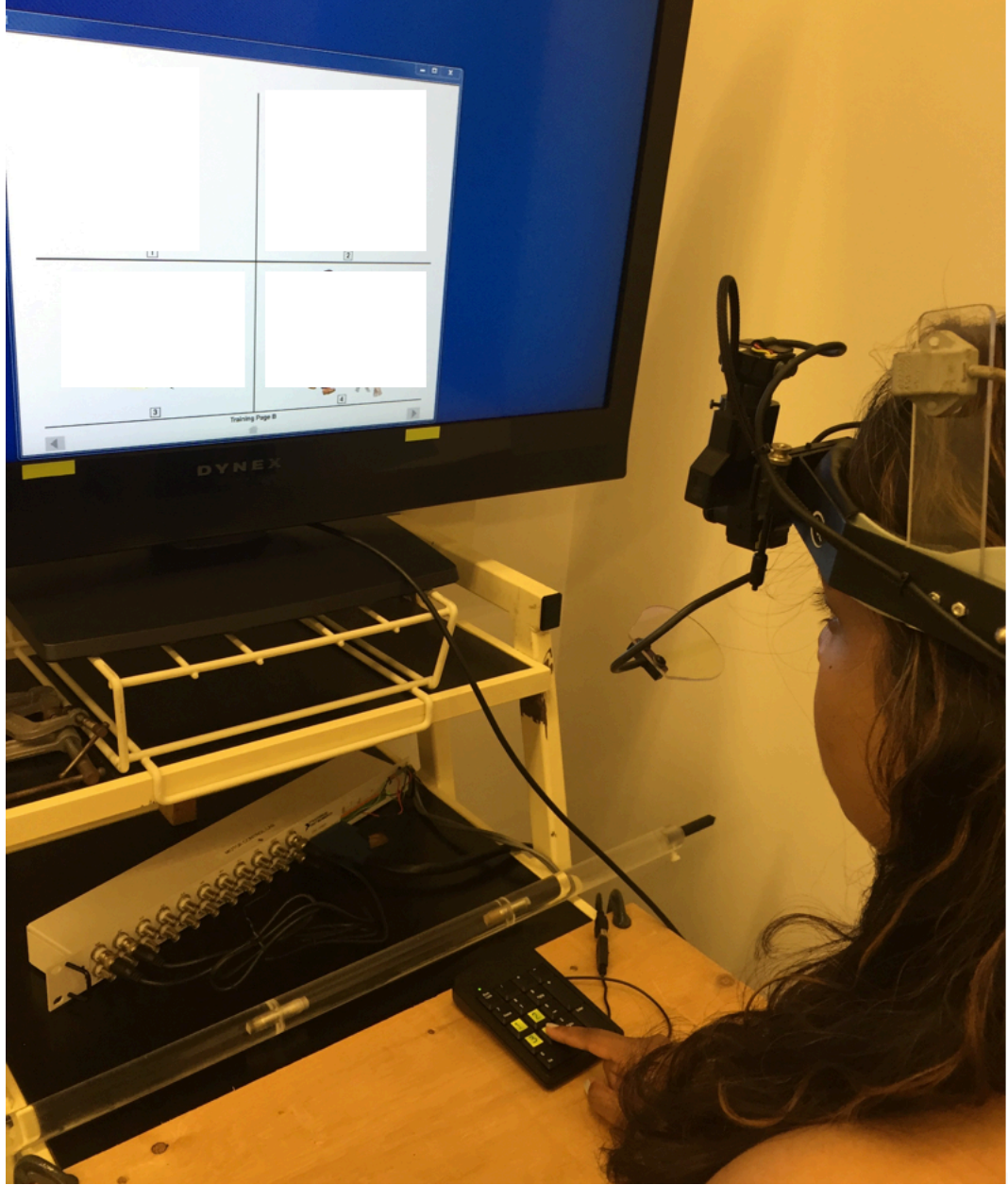
Four hierarchical regressions were done to predict impulsivity (as determined by the *BIS-11* total score and three subscales – attention, motor, and nonplanning) from eye-tracking output, reaction time, and number of self-corrections on the *PPVT-IV*. Two

hierarchical regressions used the *BIS-11* subscales (attention, motor, and nonplanning) to predict *PPVT-IV* performance (i.e., standard score and percentage of correct responses). Potentially influential demographic information was controlled for in the first step of the regression.



*Figure 2.* Mouse used for calibration and numeric keypad from which participants selected their response.





*Figure 3.* Numeric keypad from which participants selected their response.

## CHAPTER 3

### RESULTS

#### **Data Analysis**

**Preliminary Analyses.** Before proceeding to analyses, outliers and influential observations were identified and the assumptions of multiple regression analysis were tested. This data set had a good sample size according to g power ( $N=75$ ), even after outliers were trimmed ( $N=64$ ). Prior to analyses, participants were removed for one of several reasons: they could not be calibrated to the eye tracker (participants 108 and 158), they were initially calibrated but the pupil line became unreadable during testing (participants 107, 110, and 118), or had a severe hearing impairment (participant 148). The following data points are missing due to technical error: adjusted overall time (2 cases: participants 165 and 134), average speed of switching between quadrants (1 case: participant 162), average time before saccadic movement (2 cases: participants 101 and 135), and pupil dilation ratio (1 case: participant 120). A correlation matrix comparing the proposed independent variables was done to ensure variables were not related (Appendix F). Results showed no significant correlation amongst the independent variables. Since the lowest number of cards completed was 64, majority of eye tracking data analyses were for 64 of the cards (including Number of Self-Corrections, Adjusted Overall Time, Speed of Saccades, Latency to Initiate, Fixation Duration, and Number of Fixations), for a consistent comparison. Table 3 displays descriptive statistics for the continuous variables.

*Outliers/ Influential Observations.* Examination of Mahalanobis distance and leverage values revealed outliers on independent variables. Standardized residual scores

showed no outliers on the dependent variables: *BIS-11* Scores, *BIS-11* Attention subscale,

Table 3.

*Descriptive Statistics (including Mean, SD, Skewness, Kurtosis; Outliers Removed) for Continuous Variables*

Variable	Mean	Standard Deviation	Range	Skewness	Kurtosis
BIS-11 Total <sup>a</sup> (N=64)	61.05	7.96	45-81	0.00	-0.37
BIS-11 Attentional <sup>b</sup> (N=64)	17.45	3.19	10-24	-0.05	-0.41
BIS-11 Motor <sup>c</sup> (N=64)	20.84	3.18	13-29	0.03	0.58
BIS-11 Nonplanning <sup>d</sup> (N=64)	22.75	4.23	14-31	-0.15	-0.79
Average Speed of Switching Between Quadrants (N=63)	138.81	19.47	109.16-185.62 eye tracking units/s	0.71	-0.54
Avg Time Before Saccadic Movements Began (N=62)	0.08	0.08	0.01-0.37s	1.65	1.97
Ratio of Pupil Dilated vs. Not (N=63)	1.68	0.49	0.99-3.04	1.06	0.94
Average Fixation Duration per Quadrant (N=64)	0.25	0.03	0.18-0.33s	0.35	-0.73
Number of Fixations per Stimulus (N=64)	16.89	3.08	9.26-23.65	-0.29	0.22
Adjusted Overall Time for 64 Stimuli (N=64)	6.79	0.31	6.39-7.55s	0.83	0.01
Average Time/ Stimulus (N=64)	5.62	0.64	4.68-8.68s	1.70	4.54
PPVT Standard Score (N=64)	98.36	6.92	80-113	-0.24	-0.23
Correct/Number Completed (N=64)	0.68	0.09	0.37-0.85	-0.97	1.26
Number of Self-Corrections (N=64)	0.72	1.13	0-5	1.93	3.71

<sup>a</sup>BIS-11 Total Normative Sample Combined Genders M=62.3, SD=10.3

<sup>b</sup>BIS-11 Normative Sample Combined Genders Attentional M=16.7, SD=4.1

<sup>c</sup>BIS-11 Normative Sample Combined Genders Motor M=22.0, SD=4.0

<sup>d</sup>BIS-11 Normative Sample Combined Genders Nonplanning M=23.6, SD=4.9 (Stanford et al., 2009)

*BIS-11* Motor Subscale, *BIS-11* nonplanning subscale. Cook's distance revealed five cases exerting undue influence on the model. Participant 115 had the lowest *PPVT-IV* score (71;  $M=98.80$ ,  $SD=7.28$ ) and was incorrect on the first seven items, almost meeting discontinue criteria immediately, therefore this participant was removed from all analyses. This participant identified as being bilingual. Participants 119 and 126 had very slow overall reaction times (9.41min and 9.51min, respectively;  $M=6.86\text{min}$ ,  $SD=0.55$ ) and per card (8.82s and 9.09s;  $M=5.70\text{s}$ ,  $SD=0.85$ ), as well, participant 119 had the highest *BIS-11* Total score (91;  $M=61.56$ ,  $SD=8.61$ ). Participants 137 and 142 had higher *PPVT-IV* scores (111 and 115, respectively;  $M=98.80$ ,  $SD=7.28$ ) and were significantly older participants (50 and 46 years old;  $M=23.12$ ,  $SD=6.19$ ). They also appeared to have a smaller pupil dilation ratio (1.05 $\mu\text{m}$  and 1.03 $\mu\text{m}$ ;  $M=1.66\mu\text{m}$ ,  $SD=0.49$ ). Both of these individuals attended college before university (6% of participants attended college before university). Since these outliers identified on X significantly change further analyses results, these five cases were removed prior to analyses.

*Assumptions of Regressions.* Tolerance was greater than 0.10 and the variance inflation factor was less than 10 for all independent variables (Table 4; Field, 2009), suggesting that the multicollinearity was not an issue. The assumption of normality was tested. Prior to outlier trimming, review of the skewness statistics demonstrated a non-normal distribution in "Number of Self-Corrections", "Average Time/ Card", and "Adjusted Overall Time" values. The "Number of Self-Corrections" and "Average Time/ Card" kurtosis statistics also suggested a nonnormal distribution. However, majority of the histograms and boxplots of the continuous predictor variables demonstrated clear outliers. After trimming outliers, review of the skewness and kurtosis statistics suggested

Table 4.

*Tolerance and Variance of Inflation for all Independent Variables (without outliers)*

Variable	Tolerance	VIF
Average Speed of Switching Between Quadrants	0.75	1.33
Avg Time Before Saccadic Movements Began	0.44	2.26
Ratio of Pupil Dilated vs. Not	0.68	1.47
Average Fixation Duration per Quadrant	0.86	1.17
Number of Fixations per Stimulus	0.37	2.74
Adjusted Overall Time for 64 Cards	0.25	3.98
Average Time/ Card	0.24	4.25
PPVT-IV Standard Score	0.19	5.24
Correct/Number Completed	0.19	5.22
Number of Self-Corrections	0.90	1.12

N=64

that normality was a reasonable assumption, with the exception of “Number of Self-Corrections” values and “Average Time/ Card” scores, which still had skewness scores of 3.71 and 4.54, respectively (Kline, 2005). However, the boxplots suggest relatively normal distributional shapes (with almost no outliers) for all predictor variables. Before outliers were removed, a review of the scatterplot of standardized residuals to predicted values shows a concentrated display of points falling within an absolute value of 2, with three noticeable outliers. After the outliers were trimmed, a review of the scatterplot of studentized residuals to predicted values showed a random display of points falling within an absolute value of 2. However, since the distribution of the scatterplot is not a curve, we can assume linearity. The residual plot demonstrated a random pattern therefore the assumption of homoscedasticity of errors is maintained. A relatively random display of points in the scatterplots of the studentized residuals against predicted values provided evidence of independence of errors, which was controlled during data collection, through the study’s design.

### **Analyses**

In order to predict highly impulsive behaviours from the eye tracking output, four multiple hierarchical regression analyses were conducted to test the hypotheses. A stepwise analysis was done for each regression to identify which variables contribute to the predicted relationship. Impulsivity is the continuous dependent variable first determined by performance on the *BIS-11* (on which total scores can range from 30-120). Impulsivity was predicted using eye tracking output including: speed of saccades (hypothesis 1a), latency of saccades (hypothesis 1b), pupillary dilation (hypothesis 2), average fixation duration per quadrant (hypothesis 3a), number of fixations per stimulus

(hypothesis 3b), adjusted time of completion for 64 cards (hypothesis 4a), average time per stimulus (hypothesis 4b), and number of self-corrections on the *PPVT-IV* (hypothesis 5c). Table 1 shows the list of continuous independent variables that were examined using hierarchical step-wise regressions analysis to predict level of impulsivity, as measured by the *BIS-11* Total. A second hierarchical regression repeated this methodology to predict impulsivity from the Attention Subscale of the *BIS-11*. A third hierarchical regression repeated this method to predict impulsivity from the Motor Subscale of the *BIS-11*, and finally a fourth hierarchical regression repeated this method to predict impulsivity from the Nonplanning Subscale of the *BIS-11*.

In order to measure the relationship between impulsive behaviour and test results, a fifth hierarchical, step-wise regression was done using the eye tracker output and *BIS-11* subscale scores to predict *PPVT-IV* Standard Scores (hypothesis 5a). A sixth hierarchical, step-wise regression repeated this method to predict the percentage of correct responses on the *PPVT-IV* (hypothesis 5b).

**Regression Analyses Testing whether Eye tracker Output Predicts Impulsivity.** To test whether speed of saccades, latency to initiate, pupillary dilation, fixation duration per quadrant, number of fixation points, adjusted overall time of completion, average time per card, number of self-corrections on the *PPVT-IV* and background variables (ADHD diagnosis, age, gender, handedness, and SES – maternal education, household income) predict high impulsivity scores as determined by the *BIS-11* Total score, the *BIS-11* Attention Subscale, the *BIS-11* Motor Subscale, and the *BIS-11* Nonplanning Subscale, four hierarchical multiple regression analyses were conducted.

In the first step, six background variables were included: ADHD diagnosis, age,

gender, handedness, maternal education, and household income. ADHD and gender accounted for a significant amount of variance in total impulsivity scores. Speed of saccades, latency to initiate, pupillary dilation, fixation duration per quadrant, number of fixation points, adjusted overall time of completion, average time per card, and number of self-corrections on the *PPVT-IV* were entered in the second step.

ADHD diagnosis and gender, specifically males, were demographic variables found to predict variance in impulsivity, as measured by the total *BIS-11* and *BIS-11* Subscales (Attention, Motor, and Nonplanning).

A diagnosis of ADHD significantly predicted greater total *BIS-11* ratings (Table 5). ADHD also significantly predicted greater *BIS-11* Attention Subscale scores and greater *BIS-11* Motor Subscale scores (Table 5).

Gender significantly predicted variance in the total *BIS-11* ratings as well as the *BIS-11* Motor Subscale scores (Table 5), with males reporting greater *BIS-11* total and *BIS-11* Motor Subscale scores.

### **Hypothesis 1: Saccadic eye movements.**

*1a. Speed.* It was anticipated that individuals with higher impulsivity, as measured by the total *BIS-11* score and three *BIS-11* subscales (Attention, Motor, and Nonplanning), scores would demonstrate a higher average speed of saccadic movements overall, over and above ADHD, age, gender, handedness, and SES (as determined by household income and maternal education; Choi et al., 2014; Karatekin, 2007).

Hypothesis 1a was not supported by the hierarchical multiple regressions for the total



Table 5.

Stepwise Hierarchical Regressions with Eye-Tracking Data, Reaction Time, and Number of Self-Corrections on the PPVT-IV Predicting BIS-11 Total, BIS-11 Attention Subscale, and BIS-11 Motor Subscale

Independent Variable	BIS-11 Total		BIS-11 Attention Subscale		BIS-11 Motor Subscale		BIS-11 Nonplanning Subscale	
	$\beta$	95% C.I.	$\beta$	95% C.I.	$\beta$	95% C.I.	$\beta$	95% C.I.
ADHD Diagnosis	11.70*	1.13 - 22.27	5.07*	0.84 - 9.30	5.95*	1.55 - 10.36	1.89	-5.06-8.83
Age	0.10	-0.4-0.6	0.01	-0.20-0.21	0.11	-0.09-0.31	-0.01	-0.30-0.28
Gender	4.78*	0.21 - 9.36	1.32	-1.10-3.73	2.34*	0.41 - 4.26	1.99	-1.43-5.42
Handedness	-3.53	-12.31-5.26	-1.192	-4.77-2.38	-1.385	-4.90-2.13	-0.95	-6.03-4.13
Maternal Education	-1.04	-2.96-0.89	-0.582	-1.37-0.20	-0.314	-1.08-0.46	-0.14	-1.25-0.97
Household Income	-0.37	-3.29-2.56	-0.631	-1.82-0.56	-0.23	-1.40-0.94	0.5	-1.20-2.19
Average speed of switching between quadrant	0.03	-0.09-0.16	-0.005	-0.06-0.05	0.039	-0.01-0.09	0	-0.07-0.07
Average time before saccadic movements begin	-7.26	-43.71-29.19	4.351	-10.48-19.19	0.254	-14.35-14.86	-11.86	-32.94-9.21
Pupil Dilation	-5.10*	-9.06 - -1.15	-2.39*	-4.10 - -0.68	-1.85	-3.91-0.21	-1.07	-4.04-1.89
Average fixation duration per quadrant	35.05	-32.75-102.86	-0.996	-28.59-26.60	13.41	-13.75-40.57	22.64	-16.56-61.84

Independent Variable	BIS-11 Total		BIS-11 Attention Subscale		BIS-11 Motor Subscale		BIS-11 Nonplanning Subscale	
	$\beta$	95% C.I.	$\beta$	95% C.I.	$\beta$	95% C.I.	$\beta$	95% C.I.
Number of fixations per card	-0.01	-1.3-1.28	0.137	-0.39-0.66	0.141	-0.38-0.66	-0.29	-1.04-0.46
Average time for 64 Cards	2.01	-12.17-16.2	-2.732	-8.51-3.04	3.97	-1.71-9.65	0.77	-7.43-8.98
Average time/card	-0.52	-16.29-15.26	3.657	-2.76-10.08	-4.162	-10.48-2.16	-0.01	-9.13-9.11
Number of Self-Corrections	0.31	-1.53-2.15	0.455	-0.29-1.20	-0.418	-1.16-0.32	0.28	-0.79-1.34

Note. \*=Significant Results; C.I.= Confidence Interval

*BIS-11* score or the three *BIS-11* subscales.

*1b. Latency to initiate.* It was anticipated that individuals with higher impulsivity scores, as measured by the total *BIS-11* score and three *BIS-11* subscales (Attention, Motor, and Nonplanning), would demonstrate shorter average latency to initiate saccadic movements (Berlin et al., 2004; Dougherty & Marsh, 2003; Wittman & Paulus, 2008), over and above ADHD, age, gender, handedness, and SES. Hypothesis 1b was not supported by the hierarchical multiple regressions for the total *BIS-11* score or the three *BIS-11* subscales.

**Hypothesis 2: Pupillary dilation.** It was anticipated that individuals with higher impulsivity, as measured by the total *BIS-11* score and three *BIS-11* subscales (Attention, Motor, and Nonplanning), scores would show a greater ratio of pupil dilation, as measured by maximum vs. minimum pupil diameter (Cavanagh et al., 2014, de Witt, 2009; Just et al., 2003), over and above ADHD, age, gender, handedness, and SES. Hypothesis 2 was not supported by the hierarchical multiple regressions for the total *BIS-11* score or the three *BIS-11* subscales.

For the hierarchical regression predicting total *BIS-11* scores, pupillary dilation significantly added, over and above the background variables of ADHD and gender, to the amount of variance in the criterion accounted for,  $\Delta R^2 = .07$ ,  $\Delta F(1, 54) = 4.83$ ,  $p = .03$ . In the final model smaller pupil dilation was a significant predictor of higher *BIS-11* Total scores (Table 5).

For the hierarchical regression predicting *BIS-11* Attention Subscale scores, pupillary dilation significantly added, over and above the background variable of ADHD to the amount of variance in the criterion accounted for,  $\Delta R^2 = .28$ ,  $\Delta F(1, 54) = 7.87$ ,  $p =$

.01. In the final model, smaller pupil dilation was a significant predictor of higher *BIS-11* Attention Subscale scores (Table 5).

### **Hypothesis 3: Fixation points.**

*3a. Fixation duration.* It was anticipated that individuals with higher impulsivity scores, as measured by the total *BIS-11* score and three *BIS-11* subscales (Attention, Motor, and Nonplanning), would have greater fixation duration per quadrant, over and above ADHD, age, gender, handedness, and SES. Hypothesis 3a was not supported by the hierarchical multiple regressions for the total *BIS-11* score or the three *BIS-11* subscales.

*3b. Number of fixations per stimulus.* It was anticipated that individuals with higher impulsivity scores, as measured by the total *BIS-11* score and three *BIS-11* subscales (Attention, Motor, and Nonplanning), would have a higher number of fixations, or transitions per quadrant, per stimulus (Barry et al., 2005; de Wit, 2009; Dougherty & Marsh, 2003), over and above ADHD, age, gender, handedness, and SES. Hypothesis 3b was not supported by the hierarchical multiple regressions for the total *BIS-11* score or the three *BIS-11* subscales.

### **Hypothesis 4: Reaction time.**

*4a. Adjusted overall time.* It was anticipated that individuals with higher impulsivity scores, as measured by the total *BIS-11* score and three *BIS-11* subscales (Attention, Motor, and Nonplanning), would demonstrate a longer overall time of testing (de Wit, 2009; Enticott et al., 2006; Robinson et al., 2009), over and above ADHD, age, gender, handedness, and SES. Individual variation in number of stimuli would be addressed through adjusted overall time it takes to complete the first 64 cards only.

Hypothesis 4a was not supported by the hierarchical multiple regressions for the total *BIS-11* score or the three *BIS-11* subscales.

*4b. Average time per stimulus.* It was anticipated that individuals with higher impulsivity scores, as measured by the total *BIS-11* score and three *BIS-11* subscales (Attention, Motor, and Nonplanning), would demonstrate a longer amount of time per stimulus (de Wit, 2009; Enticott et al., 2006; Robinson et al., 2009), over and above ADHD, age, gender, handedness, and SES. Hypothesis 4b was supported by the hierarchical multiple regressions for the Attention Subscale of the *BIS-11* but not the Total *BIS-11* score, *BIS-11* Motor Subscale or *BIS-11* Nonplanning Subscales.

For the hierarchical regression predicting *BIS-11* Attention Subscale scores, average time per card significantly added, over and above the background variable of ADHD, to the amount of variance in the criterion accounted for,  $\Delta R^2 = .17$ ,  $\Delta F(1, 54) = 4.73$ ,  $p = .03$ . In the final model, longer average time per card was a significant predictors of higher *BIS-11* Attention Subscale scores (Table 5).

#### **Hypothesis 5: Cognitive Test Performance.**

*5c. Number of Self-Corrections.* It was anticipated that individuals with higher impulsivity scores, as measured by the total *BIS-11* score and three *BIS-11* subscales (Attention, Motor, and Nonplanning), would demonstrate a higher number of self-corrections (Boersma & Das, 2008; Ibarrola, 2009), over and above ADHD, age, gender, handedness, and SES. Individual variation in number of stimuli would be addressed through the evaluation of number of corrections for the first 64 cards only. Hypothesis 5c was not supported by the hierarchical multiple regressions for the total *BIS-11* score or the three *BIS-11* subscales.

**Regression Analysis Testing whether Higher Impulsivity Predicts Lower Cognitive Test Performance.** Results were analyzed using either *BIS-11* Total Score as an independent variable or the three subscales (attention, motor, and nonplanning) as independent variables. Since results differed based on which variables were used, results using the *BIS-11* subscales as independent variables are reported below.

To test whether speed of saccades, latency to initiate, pupillary dilation, fixation duration per quadrant, number of fixation points, the *BIS-11* Attention subscale, *BIS-11* motor subscale, *BIS-11* nonplanning subscale and background variables (ADHD diagnosis, age, gender, handedness, and SES – maternal education, household income) predict lower *PPVT-IV* performance as determined by the *PPVT-IV* Standard Score and by a lower percentage of correct responses on the *PPVT-IV*, two hierarchical multiple regression analyses were conducted.

In the first step, six background variables were included: ADHD diagnosis, age, gender, handedness, maternal education, and household income. Speed of saccades, latency to initiate, pupillary dilation, fixation duration per quadrant, number of fixation points, the *BIS-11* Attention Subscale, *BIS-11* Motor Subscale, and *BIS-11* Nonplanning Subscale scores were entered in the second step.

Household income and age were demographic variables found to predict variance in *PPVT-IV* performance (Table 6). Lower household income was a demographic variable found to significantly predict greater *PPVT-IV* standard scores and older age was a demographic variable found to significantly predict a greater percentage of correct responses on the *PPVT-IV* (Table 6).

### **Hypothesis 5: Cognitive Test Performance.**

*5a. Cognitive Test Standard Score.* It was anticipated that individuals with higher impulsivity scores, as measured by the three *BIS-11* Subscales (Attention, Motor, and Nonplanning), would demonstrate lower *PPVT-IV* Standard Scores (Förster et al., 2003; Vigneaux et al., 2006), over and above ADHD, age, gender, handedness, and SES. Hypothesis 5a was supported by the hierarchical multiple regression predicting the *PPVT-IV* Standard Score.

*BIS-11* Attention Subscale score significantly added, over and above the background variable of household income, to the amount of variance in the criterion accounted for,  $\Delta R^2 = .08$ ,  $\Delta F(1, 55) = 5.32$ ,  $p = .03$ . In the final model, greater *BIS-11* Attention Subscale scores were a significant predictor of lower *PPVT-IV* Standard Scores (Table 6).

*5b. Percent Correct on the Cognitive Test.* It was anticipated that individuals with higher impulsivity scores, as measured by the total *BIS-11* score and three *BIS-11* Subscales (Attention, Motor, and Nonplanning), would demonstrate lower percentages of correct responses, over and above ADHD, age, gender, handedness, and SES. Hypothesis 5b was not supported by the hierarchical multiple regression predicting the percentage of correct responses on the *PPVT-IV*.

Table 6. Stepwise Hierarchical Regressions with Impulsivity Attention, Motor, and Nonplanning Subscale Scores and Eye Tracker Output Predicting PPVT-IV Standard Scores and Percentage of Correct Responses on the PPVT-IV

Independent Variable	PPVT-IV Standard Score		Percent Correct on PPVT-IV	
	$\beta$	95% C.I.	$\beta$	95% C.I.
ADHD Diagnosis	-8.53	0-20.57-3.51	-0.11	-0.28-0.05
Age	0.05	0-0.42-0.51	0.01*	0.00 - 0.01
Gender	1.16	0-4.53-6.84	-0.01	-0.09-0.07
Handedness	-1.06	0-9.10-6.99	0.02	-0.09-0.13
Maternal Education	0.28	0-1.53-2.09	0.01	-0.02-0.03
Household Income	-3.06*	-5.37 - -0.75	-0.03	-0.07-0.01
BIS-11 Attention Subscale	-0.61*	-1.12 - -0.08	0.00	-0.01-0.01
BIS-11 Motor Subscale	0.13	-0.56-0.82	0.00	-0.02
BIS-11 Nonplanning Subscale	-0.37	-0.91-0.17	-0.01	-0.01

Note. \*=Significant Results; C.I.=Confidence Interval



## CHAPTER 4

### DISCUSSION

The purpose of this study was to use eye tracker output and reaction time to predict impulsivity and to explore the relationship between impulsivity and performance on assessments. Eye-tracking output, reaction time, and number of self-corrections were used to predict impulsive behaviours. Eye-tracking output and *BIS-11* scores were used to predict *PPVT-IV* performance, as well. The influence of demographic factors such as a diagnosis of ADHD, age, gender, handedness, and SES (as determined by maternal education and household income) were controlled for in these analyses, due to their potential influence on the independent and dependent variables.

It was hypothesized that high impulsivity would be predicted by eye tracking data, reaction time, and a number of self-corrections on the *PPVT-IV*. Specifically, analyses examined the relation of saccadic speed, pupillary dilation, fixation duration, reaction time, and number of self-corrections to a measure of impulsive behaviour. It was also hypothesized that impulsive behaviour would be related with *PPVT-IV* performance. Results of the present study are explored through commentary on demographic predictors and the hypotheses. There were three main findings. Results from this study demonstrated that smaller pupillary dilation and longer reaction time were related to greater self-reported levels of impulsivity. Further, greater impulsivity was related to poorer *PPVT-IV* performance. Finally, limitations, implications and conclusions are discussed.

#### **Demographic Differences**

Attention Deficit Hyperactivity Disorder (ADHD) is prevalent in approximately

5% of the Canadian population (CMHO, 2015), which is consistent with the number of participants diagnosed with ADHD in the present study. Despite a diagnosis of ADHD being present in a small sample of the participants, analyses determined that ADHD was a prominent predictor of self-reported overall impulsivity, as well as attentional and motor impulsivity. These findings are unsurprising when considering the diagnostic criteria for attention deficit hyperactivity disorder which can be characterized by inattention (related to attentional impulsivity) and hyperactivity (related to motor impulsivity; APA, 2013; Stanford et al., 2009). A review of impulsive behaviours in adults with ADHD showed that ADHD groups displayed more signs of impulsivity on the three dimensions of the *BIS-11* when compared to a “healthy” comparison group (Malloy-Diniz, Fuentes, Leite, Correa, & Bechara, 2007). The authors concluded that such results supported the idea that individuals with ADHD, therefore, are experiencing deficits in motor, cognitive, and attentional impulsivity (Malloy-Diniz et al., 2007).

There were notable sex differences in individuals reporting on motor impulsivity, with males in the sample generally reporting higher impulsivity. This finding is consistent with the literature. In a review on normative data of the *BIS-11*, males were found to score higher in impulsivity (Spinella, 2007).

Lower household income, an indicator of socioeconomic status, was related to greater *PPVT-IV* Standard Scores. Findings were not consistent with the research. Research demonstrates that, individuals from higher socio-economic backgrounds tend to have greater lexical development (Hoff & Tian, 2005). It is possible that participants in this study inaccurately portrayed their household income, since 33% of participants reported having a household income of greater than \$100 000. In Canada, approximately

4% of the population have a household income of greater than \$100 000 (Statistics Canada, 2015).

Older participants were found to have a greater percentage of correct responses on the PPVT-IV. Age has been implicated as a factor that is related to receptive vocabulary abilities (Bialystok & Luk, 2012), with older individuals having greater vocabulary, as was demonstrated in this study. Since the PPVT-IV standard score controls for these differences (Dunn & Dunn, 2007), age difference were only present when predicting the percentage of correct responses.

### **Saccadic Movements and Impulsivity**

Results did not support the hypotheses that individuals with higher impulsivity would demonstrate a higher average speed of saccadic movements overall and a shorter average latency to initiate saccadic movements. Saccadic movements are a shift in visual-spatial attention; it is possible that differences in speed of saccades are more prominent in individuals with a diagnosis of ADHD rather than population variations in impulsivity (Choi et al., 2014; Martinez-Conde, Macknik, & Hubel, 2004). Furthermore, saccadic speed is calculated as a ratio of saccadic movements over reaction time. There was some evidence that individuals with higher impulsivity have a slower reaction time due to attentional lapses (de Wit, 2009). Therefore, though there may have been more saccadic movements and amplitude overall, they might have been factored out of the ratio due to reaction time.

### **Pupillary Dilation and Impulsivity**

Results did not demonstrate that individuals with higher impulsivity had a greater ratio of pupil dilation. Rather, it was found that greater pupillary dilation predicted lower

overall and attentional impulsivity scores. These findings may reflect that the *PPVT-IV* is not a high arousal task. Individuals with ADHD have been identified as having lower levels of base arousal (Loo et al., 2009). It is possible that individuals who rated high on attentional impulsivity demonstrated lower arousal, which may be related to their pupil dilation. As well, pupil dilation on the eye tracker, like on many behavioural measures of impulsivity, is state-dependent (Marshall, 2007), whereas self-report measures of impulsivity are trait dependent (Stanford et al., 2009). Therefore, this finding may be reflective of impulsive behaviours that are not consistently captured in self-report measures. Alternatively, it is possible that these findings are reflective of narrowed attention. To date, studies on pupillometry suggest pupil dilation is related to arousal, with greater dilation being related to greater arousal. Therefore, if smaller pupil dilation is indicative of narrowed attention and high arousal, a finding such as this, may contribute to reconsidering how to conceptualize physiological arousal and interpret pupil dilation. A future direction of research could further investigate the physiological reaction to a narrowed attentional focus and how it may reflect the opposite of what was previously anticipated with high arousal tasks (e.g., tasks with high cognitive load). Further investigation into the relationship between pupillometry, focused attention, and impulsivity is warranted.

### **Fixation Points and Impulsivity**

Results did not show individuals with higher impulsivity as having shorter fixations per quadrant nor did they show that individuals with higher impulsivity had a higher number of fixations, or transitions per quadrant, per stimulus. Fixation duration is useful for determining how long an area of interest holds an individual's visual attention, as

determined by eye movement (Karatekin, 2007). It is possible that the task was shorter and more engaging than some other tasks, and therefore nuanced attentional differences, such as in number of fixations, might not be a good indication of attention or impulsivity on a cognitively engaging task with short duration. It is also possible that fixation points were not a reliable measure of impulsivity if participants with attentional difficulties looking off-screen, which is not counted by the eye tracker as fixations. Further research is necessary to determine if on longer or less engaging tasks, fixation duration and number of fixations might emerge as predictors of inattention and impulsivity.

### **Reaction Time and Impulsivity**

Results did not demonstrate that individuals with higher impulsivity had a higher adjusted overall time of testing. Because the stimuli had a cut-off point of 64 cards for analyses (the lowest number of stimuli completed), it is possible that individuals with high impulsivity may demonstrate similar reaction times as individuals who are not highly impulsive until a certain level of cognitive load. It is possible that analyses of card 65-83 in individuals with higher impulsivity shows a decrease in reaction time due to an increase in cognitive load, as stimulus words become less familiar. This pattern would explain why individuals with higher attentional impulsivity demonstrated slower average time per stimulus, a finding that supports hypothesis 4b. A slower reaction time per stimulus is a pattern that is indicative of slower reaction time, which is consistent with the literature. A slower reaction time for individuals with high impulsivity may be due to lapses in attention, resulting in lost time (de Wit, 2009).

In this study, reaction time was dependent on participants pushing a button to indicate their answer, meaning that the decision-making process and answer choice, made

prior to physically responding, were not captured in this study. It is possible that reaction time results would differ if the time taken to make a decision, prior to physically moving to push a button, was captured, particularly in individuals with high impulsivity. One direction of future research is to capture pre-reaction decision-making by having participants place their finger on a designated spot and lift their finger to respond the moment they make a decision.

### **Impulsivity and Cognitive Test Performance**

Individuals with higher impulsivity exhibited lower *PPVT-IV* standard scores. Standard scores are calculated based on age and number of correct responses. This finding may be indicative of lapses in attention, characteristic of individuals with high impulsivity (Corr, 2004; Richards et al., 2011; Winstanley et al., 2006), which further corroborates the longer reaction time finding. However, results did not demonstrate that the percentage of correct responses was related to level of impulsivity. Future research should look at test performance scores that are reflective of percentage correct.

Results did not demonstrate that the number of self-corrections was reflective of level of impulsivity. Individuals with higher impulsivity may have had fewer self-corrections due to the slower reaction time demonstrated. Participants had a 2-second window to make a self-correction after responding before the next stimulus appeared. Most participants did not make any self-corrections.

### **Study Limitations**

There are a few limitations in the present study. First, the sample was collected from a university population. Test performance abilities, demographic variables (e.g., SES), reaction time, and level of impulsivity are likely to differ from those found in the

general population. For instance, individuals with high impulsivity who have reached university may have higher adaptive functioning than those who have not pursued higher education and may have developed compensatory strategies to manage their impulsivity. Similarly, there was a ceiling effect in the current study, where majority of participants completed all 83 cards, which may be less likely in a population of individuals with lower levels of education or lower SES. As well, it is possible that participants overestimated their household income (i.e., maternal and paternal income). Therefore, the generalizability of these findings is limited. Future research can adapt this methodology to a community population.

Second, this study relied on self-report measure of impulsivity. As mentioned, these measures do not clearly map onto behavioural measures of impulsivity (Reynolds et al., 2006). Further studies should be conducted using multiple measures of impulsivity, with the addition of behavioural observations and reports from other raters (e.g., parents) to corroborate findings.

Third, this study utilized eye tracking measures. With eye tracking data, many of the results computed are used to make inferences about underlying processes. It is possible that some findings may be artifacts of the methodology and it is also possible that other variables that are not accounted for are influencing results. The findings suggest that pupil dilation would be beneficial to consider in future investigations of attention, cognitive load, and impulsivity.

### **Implications and Conclusion**

With regards to the disparity between self-report and behavioural measures of impulsivity, this study demonstrated the potential use of pupillometry and reaction time

as behavioural measures that have a notable relationship with self-reported impulsivity. The nature of impulsive behaviour and attention are that studies must be designed in such a way that these behaviours can be inferred. Studies on pupillometry offer some insight with regards to an individual's present mental state (Marshall, 2007). Studies have demonstrated that pupil dilation is sensitive to working memory load and correlated to greater task difficulty (Just et al., 2003). As mentioned, greater pupil dilation can be indicative of slower reaction time, as was found in this study.

Further analyses, dividing the PPVT-IV stimuli into easy, medium-difficulty, and difficult groups and measuring reaction time within these groups could provide insight into both pupillometry (and potential attentional focus effects vs. cognitive load) and reaction time. It would also be interesting to see if analyses of separate stimulus groups would result in notable differences in fixation duration, number of fixation points, overall reaction time per sub-section, latency to initiate saccades, and speed of switching quadrants.

Ultimately, this study revealed that behavioural information could be used to predict self-report measures of impulsivity. These findings can be used to develop behavioural measures that tap into the subtle processes captured in self-report measures and are of particular significance to populations working with individuals with impulsivity. The findings of this study also suggest that impulsive behaviours are related to test performance.

Objective behavioural data captured during an assessment is an important finding for overall test validity. In this study, lower pupil diameter was predictive of higher ratings of total, motor, and attentional impulsivity and slower reaction time was



predictive of higher ratings of attentional impulsivity. Greater impulsivity ratings, in turn, were predictive of lower PPVT-IV standard scores. These results raise the question of whether individuals with greater levels of impulsivity are testing to the best of their ability. The participants in this study had population-occurring variation of impulsivity. These results are relevant to Psychologists and test-administrators, as well, they have the potential to be further applied to the education system by providing some information regarding the validity of test performance in schools in the average classroom. Further research is needed on this subject to determine a causal relationship between impulsivity and test performance and to determine what can be done to curb these potential effects. The use of an impulsivity measure or reaction time measure in combination with an assessor's observations has the potential to increase the validity of a subject's performance by adding an objective element to behavioural observations. Future research should also pair eye tracker data with behavioural observations to better understand the eye tracker results, if, for instance, the participant is frequently looking off-screen.

The increased use of eye tracking in research has resulted in the advancement of our understanding of various cognitive processes including attention (Karatekin, 2007; van Gog & Schieter, 2010). In the present study, eye tracking was used to extract new behavioural information (impulsivity) to provide insight into the decision-making process that occurs during testing that is not being measured empirically in traditional paper-pencil administration of cognitive tests. Greater levels of impulsivity were found to relate to lower test scores. Impulsivity ratings were notably related to ADHD diagnosis and gender, while *PPVT-IV* scores were related to age and household income. These findings are of both theoretical and practical importance as technology in psychological practice

and testing advances.

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## APPENDICES

### **Appendix A: Participant Pool Advertisement**

**Study name:** Using Eye Tracking to Measure the Decision Making Process

**Brief Abstract:** The purpose of this study is to understand more about the decision-making process that occurs during testing. An eye tracker to measure the visual process that takes place while making a decision. If you agree to participate, you will complete a visual task that measures receptive verbal skills while wearing the eye tracker and fill out a brief questionnaire.

**Description:** Participants will meet in room 203 of the Human Kinetics Building. Participants will wear an eye tracker for 30 minutes to complete a multiple-choice computer task after which they will complete a brief questionnaire.

**Eligibility requirements:** English as a first language, undergraduate students.

**Study Duration:** 60 minutes

**Points/Pay:** 1 point for 60 minutes of completion

**Preparation:** None

**Researcher:** Abirami R Kandasamy

**Email:** kandasaa@uwindsor.ca

**Participant Sign-up Deadline:** 48 hours before the study is to occur

**Pre-requisites:** None

**Disqualifiers:** None

**Course Restrictions:** None

## Appendix B: Demographic Form

### Demographic Information

*Please answer the following questions about yourself by selecting the appropriate choice and/or using the space provided:*

Age<sup>1</sup> (Years, Months, Days – e.g., 22yrs, 10mos, 1 day): \_\_\_\_\_

Initials: \_\_\_\_\_

Current Date (month/day/year): \_\_\_\_\_

Gender: \_\_\_\_\_

Handedness:  Right-handed  Left-handed

Highest Level of Education (e.g., high school, first year of undergrad): \_\_\_\_\_

Year of Study (e.g., 2<sup>nd</sup> year): \_\_\_\_\_

Program of Study (e.g., Double Major – Psychology & English): \_\_\_\_\_

Physical Impairment (select all that apply):

Visual Impairment (e.g., wear corrective lenses);

Specify: \_\_\_\_\_

Hearing Impairment (e.g., wear hearing aid); Specify: \_\_\_\_\_

Other;

Specify: \_\_\_\_\_

Diagnoses of physical or mental health difficulties (i.e., ADHD, anxiety, depression): -

Maternal Income (select one): Maternal Occupational Field (select one):

less than \$5 000  Management

\$5 000 to \$9 999  Business, finance and administration

\$10 000 to \$19 999  Natural and applied science or related occupations

\$20 000 to \$29 999  Health

\$30 000 to \$39 999  Social Science, Education, Government, or Religion

<sup>1</sup>Researcher will assist in calculating exact age



- \$40 000 to \$49 000  Art, culture, recreation and sport
- \$50 000 to \$59 999  Sales and Service
- \$60 000 to \$69 999  Trades, transport and equipment operator or related occupation
- \$70 000 to \$79 999  Occupation unique to primary industry
- \$80 000 to \$89 999  Occupation unique to processing, manufacturing and utilities
- \$90 000 to \$99 999  Occupation unique to processing, manufacturing and utilities
- \$100 000 or more  Other
- Prefer not to answer  Other

Highest Level of Maternal Education: \_\_\_\_\_

Paternal Family Income (select one): Paternal Occupational Field (select one):

- less than \$5 000  Management
- \$5 000 to \$9 999  Business, finance and administration
- \$10 000 to \$19 999  Natural and applied science or related occupations
- \$20 000 to \$29 999  Health
- \$30 000 to \$39 999  Social Science, Education, Government, or Religion
- \$40 000 to \$49 000  Art, culture, recreation and sport
- \$50 000 to \$59 999  Sales and Service
- \$60 000 to \$69 999  Trades, transport and equipment operator or related occupation
- \$70 000 to \$79 999  Occupation unique to primary industry
- \$80 000 to \$89 999  Occupation unique to processing, manufacturing and utilities
- \$90 000 to \$99 999  Occupation unique to processing, manufacturing and utilities
- \$100 000 or more  Other
- Prefer not to answer  Other

Highest Level of Paternal Education: \_\_\_\_\_

Culture/Ethnicity (select all that apply):

- South Asian
- Asian (e.g., Chinese, Japanese)
- Black
- White/Caucasian
- Latin American
- Southeast Asian
- Arab
- Other (please specify): \_\_\_\_\_

1<sup>st</sup> Language Spoken in home:

- English  French  Other (please specify): \_\_\_\_\_

Other languages spoken in home (please specify):

\_\_\_\_\_

## Appendix C: Consent Form



### CONSENT TO PARTICIPATE IN RESEARCH

Title of Study: Using Eye tracking to Measure the Decision-Making Process

You are asked to participate in a research study conducted by Abirami Kandasamy under the supervision of Dr. Sylvia Voelker from the Department of Psychology, University of Windsor. If you have any questions or concerns about this research please feel free to contact Abirami Kandasamy at [kandasaa@uwindsor.ca](mailto:kandasaa@uwindsor.ca) or Dr. Sylvia Voelker, through email ([voelker@uwindsor.ca](mailto:voelker@uwindsor.ca)). The results from this study will form the basis of a Master's thesis research project, which is supported by the Social Science and Humanities Research Council of Canada.

### PURPOSE OF THE STUDY

The purpose of this study is to measure eye movements in relation to a receptive vocabulary task and see how eye movements relate to decision-making processes as measured by a computer task and a brief questionnaire.

### PROCEDURES

If you volunteer to participate in this study, you will be asked to:

Meet in the Motor Lab of the Human Kinetics Department located in room 203 in the Human Kinetics Building where the research study will take place for 1 hour. You will first read and consent to the study as well as ask any questions pertaining to consent or details about the study (10 minutes). You will then complete a demographic information form (5 minutes).

#### Eye tracker

You will use an eye tracker by putting on a headgear (weight=0.75lbs) and be calibrated to a computer screen on which you will complete a visual language task (maximum 30 minutes for calibration and task). The visual language task measures receptive vocabulary, which can provide information on cognitive abilities. The eye tracker will then be removed and the headgear will be swabbed with alcohol. The eye tracking equipment is cleaned between each use.

#### Brief Questionnaire

Finally, you will answer a brief questionnaire on real-world actions and decisions in which you regularly take (maximum 15 minutes).

## POTENTIAL RISKS AND DISCOMFORTS

There are no direct benefits of this research to you. However, you will gain exposure to eye tracking technology and research method. This study also informs on the subject of computerized assessment, which is an important aspect of the education system and may have benefit to society in the context of education.

## POTENTIAL BENEFITS TO PARTICIPANTS AND/OR TO SOCIETY

There are no direct benefits of this research to participants. Participants will gain exposure to eye tracking technology and research method. This study also informs on the subject of computerized assessment, which is an important aspect of the education system and may have benefit to society in the context of education.

## COMPENSATION FOR PARTICIPATION

You will receive 1 bonus point for 60 minutes of participation towards the psychology participant pool, if you are registered in the pool and enrolled in one or more eligible courses.

## CONFIDENTIALITY

Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission. All of the information that is collected (demographic information, eye tracking output, and questionnaire scores) will be kept private and will only be accessed by researchers directly involved with the study. The information collected will be stored in an electronic database on a secure server, which is password-protected. The data will be kept on an encrypted USB and on a secure computer in a locked office. Your name and email will be required for compensation (participant pool points) but it will be deleted once the bonus marks have been assigned and semester grades have been submitted. The information from this study may be published at a later date and may be used in future analyses, but only group information and no personally-identifying information will be discussed. In accordance with the guidelines of the American Psychological Association, your data will be kept for five years following the last publication of the data. If the data are not used for subsequent research or will not be published, the data will be destroyed.

## PARTICIPATION AND WITHDRAWAL

**You have the right to withdraw from this study at any point during the 1 hour allocated time and for up to 24 hours after the study has taken place, after which data will be deidentified.** The investigator may withdraw you from this research if circumstances arise which warrant doing so. Your data (results) will be destroyed if you chose to withdraw within 24 hours of participating in the study but your information (name and participant ID number) will be kept in order to allocate points when appropriate. You

will be allocated points in ratio to the content completed. A maximum of 1 point will be allocated to this study. You will receive full points for completing all of the tasks. If you complete only one of the items, a minimum of 0.5 points will be allocated (but these data will not be useable). After the data are deidentified, you will no longer be able to request that your data be withdrawn.

#### FEEDBACK OF THE RESULTS OF THIS STUDY TO THE PARTICIPANTS

A summary of research findings will be available to you upon completion of the project on the Research Ethics Board website, <http://www1.uwindsor.ca/reb/study-results>.

Email address: Abirami Kandasamy [kandasaa@uwindsor.ca](mailto:kandasaa@uwindsor.ca)

Date when results are available: October 1, 2014

#### SUBSEQUENT USE OF DATA

The data from this study may be used in future research.

#### RIGHTS OF RESEARCH PARTICIPANTS

If you have questions regarding your rights as a research participant, contact: Research Ethics Coordinator, University of Windsor, Windsor, Ontario, N9B 3P4; Telephone: 519-253-3000, ext. 3948; e-mail: [ethics@uwindsor.ca](mailto:ethics@uwindsor.ca)

#### SIGNATURE OF RESEARCH PARTICIPANT/LEGAL REPRESENTATIVE

I understand the information provided for the study Using Eye tracking to Measure the Decision-Making Process as described herein. My questions have been answered to my satisfaction, and I agree to participate in this study. I have been given a copy of this form.

\_\_\_\_\_  
Name of Participant

\_\_\_\_\_  
Signature of Participant

\_\_\_\_\_  
Date

#### SIGNATURE OF INVESTIGATOR

These are the terms under which I will conduct research.

\_\_\_\_\_  
Signature of Investigator

\_\_\_\_\_  
Date

## **Appendix D: Debriefing Script**

Thank you for your participation we request that you keep the information of this study confidential. We are interested in understanding more about how impulsivity impacts the decision-making process that occurs during testing. Technological advances are changing the way testing is done. Online and computer administration of psychological services continue to grow in popularity. Impulsivity is a behaviour that can impact testing results, but is difficult to measure in traditional testing procedures (i.e., paper and pencil administration). An individual with high impulsive behaviours during testing may have results that are not representative of his/her actual abilities. For example, if the individual was impulsive, he/she may not have looked at all four of the multiple choice options before answering. We hope to predict impulsivity by looking at the individual's eye scanning patterns and test results using the eye tracking equipment. We hope that this research study will give us a better understanding of computerized assessment, which is also an important aspect of the education system and may have benefit to society in the context of education. Your data will be kept confidential, accessible only by the researchers, and once all participants have been compensated with participant pool points, any of your identifying information will be deleted. Please contact me, Abi, or my supervisor, Dr. Voelker, if you have any questions or concerns about this study. Our email addresses are on the letter of consent that you will be taking home. If you wish to withdraw your data, please email us within 24 hours of completing this study. Once the study is finished, you will be able to view the results from the study on the Research Ethics Board website at <http://www1.uwindsor.ca/reb/study-results>, the website can also be found on your letter of consent. Again, thank you for your participation.

## Appendix E: Letter of Information



### LETTER OF INFORMATION FOR CONSENT TO PARTICIPATE IN RESEARCH

Title of Study: Using Eye tracking to Measure the Decision-Making Process

You are asked to participate in a research study conducted by Abirami Kandasamy under the supervision of Dr. Sylvia Voelker from the Department of Psychology, University of Windsor. If you have any questions or concerns about this research please feel free to contact Abirami Kandasamy at [kandasaa@uwindsor.ca](mailto:kandasaa@uwindsor.ca) or Dr. Sylvia Voelker, through email ([voelker@uwindsor.ca](mailto:voelker@uwindsor.ca)). The results from this study will form the basis of a Master's thesis research project, which is supported by the Social Science and Humanities Research Council of Canada.

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#### Brief Questionnaire

Finally, you will answer a brief questionnaire on real-world actions and decisions in which you regularly take (maximum 15 minutes).

## POTENTIAL RISKS AND DISCOMFORTS

Anticipated risks of this research project include possible mild discomfort from wearing the eye tracker headgear for 30 minutes (0.75lbs). You will be asked about your comfort level when wearing the eye tracker headgear. If at any point while wearing the eye tracker headgear you experience any discomfort, we will remove the eye tracker.

## POTENTIAL BENEFITS TO PARTICIPANTS AND/OR TO SOCIETY

There are no direct benefits of this research to you. However, you will gain exposure to eye tracking technology and research method. This study also informs on the subject of computerized assessment, which is an important aspect of the education system and may have benefit to society in the context of education.

## COMPENSATION FOR PARTICIPATION

You will receive 1 bonus point for 60 minutes of participation towards the psychology participant pool, if you are registered in the pool and enrolled in one or more eligible courses.

## CONFIDENTIALITY

Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission. All of the information that is collected (demographic information, eye tracking output, and questionnaire scores) will be kept private and will only be accessed by researchers directly involved with the study. The information collected will be stored in an electronic database on a secure server, which is password-protected. The data will be kept on an encrypted USB and on a secure computer in a locked office. Your name and email will be required for compensation (participant pool points) but it will be deleted once the bonus marks have been assigned and semester grades have been submitted. The information from this study may be published at a later date and may be used in future analyses, but only group information and no personally-identifying information will be discussed. In accordance with the guidelines of the American Psychological Association, your data will be kept for five years following the last publication of the data. If the data are not used for subsequent research or will not be published, the data will be destroyed.

## PARTICIPATION AND WITHDRAWAL

**You have the right to withdraw from this study at any point during the 1 hour allocated time and for up to 24 hours after the study has taken place, after which data will be deidentified.** The investigator may withdraw you from this research if

circumstances arise which warrant doing so. Your data (results) will be destroyed if you chose to withdraw within 24 hours of participating in the study but your information (name and participant ID number) will be kept in order to allocate points when appropriate. You will be allocated points in ratio to the content completed. A maximum of 1 point will be allocated to this study. You will receive full points for completing all of the tasks. If you complete only one of the items, a minimum of 0.5 points will be allocated (but these data will not be useable). After the data are deidentified, you will no longer be able to request that your data be withdrawn.

#### FEEDBACK OF THE RESULTS OF THIS STUDY TO THE PARTICIPANTS

A summary of research findings will be available to you upon completion of the project on the Research Ethics Board website, <http://www1.uwindsor.ca/reb/study-results>.

Email address: Abirami Kandasamy kandasaa@uwindsor.ca

Date when results are available: October 1, 2014

#### SUBSEQUENT USE OF DATA

The data from this study may be used in future research.

#### RIGHTS OF RESEARCH PARTICIPANTS

If you have questions regarding your rights as a research participant, contact: Research Ethics Coordinator, University of Windsor, Windsor, Ontario, N9B 3P4; Telephone: 519-253-3000, ext. 3948; e-mail: [ethics@uwindsor.ca](mailto:ethics@uwindsor.ca)

#### SIGNATURE OF RESEARCH PARTICIPANT/LEGAL REPRESENTATIVE

I understand the information provided for the study Using Eye tracking to Measure the Decision-Making Process as described herein. My questions have been answered to my satisfaction, and I agree to participate in this study. I have been given a copy of this form.

\_\_\_\_\_  
Name of Participant

\_\_\_\_\_  
Signature of Participant

\_\_\_\_\_  
Date

#### SIGNATURE OF INVESTIGATOR

These are the terms under which I will conduct research.

\_\_\_\_\_  
Signature of Participant

\_\_\_\_\_  
Date



## Appendix F: Correlation Matrix

### Correlation Between BIS-11 Subscales, Eye tracking, Reaction Time, and PPVT-IV

#### Performance

Variable	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.
1. BIS-11 Attentional N=64													
2. BIS-11 Motor N=64	.28*												
3. BIS-11 Nonplanning N=64	.43**	.29*											
4. Average Fixation Duration per Quadrant N=64	0.11	0.07	0.17										
5. Number of Fixations per Stimulus N=64	0.01	-0.02	-0.11	-0.06									
6. Ratio of Pupil Dilated vs. Not N=63	.37**	-.32*	-0.23	-0.16	0.01								
7. Avg Time Before Saccadic Movements Began N=62	-0.08	-0.08	-0.13	0.01	-.57**	0.17							
8. Average Speed of Switching Between Quadrants N=63	-0.17	-0.02	-0.14	-.29*	0.09	.36**	0.07						
9. Average Time/ Card N=64	0.05	-0.07	-0.02	0	.50**	.31*	-	0.01	0.14				
10. Adjusted Overall Time for 64 Cards N=64	0.03	-0.05	0.028	-0.04	.50**	.29*	0.02	0.11	.98**				
11. PPVT Standard Score N=64	-0.21	-0.07	-.25*	0.18	-0.125	0.02	0.19	-0.01	-0.16	-0.15			
12. Correct/ Incorrect Responses on PPVT- IV N=64	-0.08	0.07	-0.21	0.2	-0.07	-0.16	0.12	-0.11	-0.17	-0.16	.88**		
13. Number of Self- Corrections N=64	0.15	-0.07	0.1	-0.03	0.076	-0.03	-	0.04	-0.05	0	0.02	-.26*	-.26*

Note. \*Correlation is significant at the 0.05 level; \*\*Correlation is significant at the 0.01 level

## VITA AUCTORIS

NAME: Abirami R Kandasamy

PLACE OF BIRTH: Montreal, QC

YEAR OF BIRTH: 1987

EDUCATION: Middlefield Collegiate Institute, Markham, ON,  
2005  
University of Western Ontario, B.Sc., London,  
ON, 2009  
York University, B.Sc., Toronto, ON, 2012