On-Task: Increasing attentiveness in students with ADHD

by

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Abstract

Attention Deficit/Hyperactivity Disorder (ADHD) is a very social problem and is one of the most common mental health conditions in children (Statistics Canada, 2012). With recent changes in camera resolution, I designed an app that tracked the students’ eye-movements and adaptively delivered rewards and reminders to modify their behaviours. The goal of this research was to increase attentiveness and reduce distractibility in students aged between six and thirteen diagnosed with ADHD. Additionally, it tried to determine what feedback could be provided to help them in their study efforts. All of the participants that completed the intervention reported increased attention and decreased distractibility. Additionally, most of the participants reported transferability of these behaviours to an external environment, specifically, school. One participant indicated he had better self-esteem as a result of the intervention. These results show that a technological intervention can help students with ADHD increase their attentiveness and reduce their distractibility.
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Chapter 1 – Introduction

Attention Deficit Hyperactivity Disorder (ADHD) affects an ever-increasing population (CDC, 2012), but until very recently, the resolution of front-facing cameras on smart devices had not increased enough to allow for relatively low-cost technological interventions to help students with ADHD with their ability to control attentiveness and distractibility. As part of this introduction, and to give you some background, the origins of the disorder, biological testing, the power of technology, and the purpose of this research will be outlined. Additionally, and in order to provide the necessary context to clearly describe this research, it will be necessary to outline a few key areas. Those key areas are the theoretical frameworks, the problem statement and research questions, the limitations and delimitations, ending with a definition of key terms.

Origins

The literature shows the first signs of ADHD in 1798 with the publication of Sir Alex Crichton’s second book, On Attention and its Diseases, in which, he characterizes the disorder as, “the incapacity of attending with a necessary degree of constancy to any one object.” Indeed, Crichton gives “several indications that he was depicting the same disorder as defined in the current [Diagnostic and Statistical Manual of Mental Disorders] DSM-IV criteria of ADHD,” (Lange et al, 2010, p. 242).

In the mid-1800s, German physician Heinrich Hoffmann used paper from his notebook to make “little drawings to calm and amuse crying children, thus making possible an undisturbed medical examination,” (Lange et al, 2010, p. 242). These drawings were added to stories and were turned into a children’s book in 1845. In the second edition of the book, Hoffmann added more stories including one about a boy that cannot sit still at the dinner table; Fidgety Phil
(“Zappelphilipp”) (Hoffmann, 1985), who is now a popular metaphor for children with ADHD (Lange et al, 2010, p. 243).

At the turn of the 20th century, Sir George Still wrote extensively on the disorder, and his Goulstonian Lectures, a series of three lectures to the Royal College of Physicians of London *On Some Abnormal Psychical Conditions in Children* (Still, 1902) are, by many authors, considered to be the scientific starting point of the history of ADHD, (Lange et al, 2010). Still recounts 20 cases involving children with a “defect of moral control as a morbid manifestation, without general impairment of intellect and without physical disease,” (1902, p. 1079). Unfortunately, most of the symptoms described by Still do not refer specifically to ADHD and many are more recognizable in other, possible comorbid disorders, (Conners, 2003).

As research into the disorder discovered more signs and symptoms, it went through a number of name changes. In the 1930s, ADHD was termed, “minimal brain damage” (Strauss & Kephart, 1955), changing into “minimal brain dysfunction” (Weiss, Hechtman & Weiss, 2010), because many children with no indication of brain damage also exhibited signs of the disorder. After a number of additional name changes recorded through the earlier versions of the DSM, the current term, Attention Deficit Hyperactivity Disorder (ADHD) with three subtypes has been used since the DSM-IV, published in 1994.

**Biological Testing**

In his 1985 article, “Eye Movements in Dyslexia: Their Diagnostic Significance,” George Pavlidis suggests, “There is a consensus of opinion among eye movement researchers that a high number of dyslexics exhibit erratic eye movements during reading” (p.44). His measurements combined the four individual basic eye movement types (saccades, smooth pursuit eye
movements (SPEM), vergence movements, and/or vestibulo-ocular movements) into patterns to allow for comparison (Pavlidis, 1985, p. 44). Since the similarities between dyslexia and ADHD are numerous, and because the two disorders can be comorbid, the results of this research compliment my research. Indeed, “like ADHD, dyslexia can cause a wide range of learning difficulties at school; this condition does not reflect the intelligence of a sufferer, as it can affect anyone of high or low intelligence,” (Pendower, 2012). Unfortunately, Pavlidis’ studies do not include the eye movements of students with ADHD; dealing only with dyslexia, indicating additional research into this area is obviously needed.

In 2000, Randal Ross and research team published a paper in the Society of Biological Psychiatry in which they endeavour to assess if the SPEM abnormalities present in schizophrenics were also present in adults with ADHD, given that both maladies have chronic attentional and inhibitory dysfunction (Ross et al, 2000, p. 197). Although the eye movements between the ADHD and schizophrenic were significantly different, the ADHD group did not differ from the control group, suggesting that “the general attentional and inhibitory dysfunction associated with ADHD does not translate into major SPEM abnormalities in the majority of ADHD patients,” (Ross et al, 2000, p. 201).

Recent research into the differences in brain waves between people with ADHD and those without the disorder indicate that there are noticeable differences (Mazaheri et al, 2013). In the Mazaheri et al. research, they found that by studying the readings from an electroencephalogram (EEG) of 23 children they were able to distinguish not only between ADHD and non-ADHD students, but were able to accurately separate and identify the different subtypes. (Mazaheri et al, 2013, p. 427). Unfortunately, children that live in rural or northern
locations may have to travel many hundreds of kilometers to gain access to an EEG, making this an unrealistic method of testing these individuals.

**The Power of Technology**

According to Moore’s law, the number of transistors in a dense integrated circuit doubles approximately every two years (Moore, G., 1998). This law has very wide-ranging implications as it guides everything from the semiconductor industry in long-term planning to quality-adjusted microprocessor prices to memory capacity to sensors to the number and size of pixels in digital cameras. “Smartphones today are exceptionally smaller, cheaper and more powerful than the supercomputers of forty years ago. What used to fill a whole city block now fits in your pocket for a fraction of the price, and the average consumer has access to some of the most powerful computing power once restricted for the use of top secret government departments” (Pulla, 2014, p. 10). Recent strides in computer vision (CV) and even more important advances in open-source versions of CV (Open-CV) are allowing more and more people to push the limits of technology by defining new uses for it. One example of such CV innovation is “A Computer Vision-Based System for Real-Time Detection of Sleep Onset in Fatigued Drivers,” (Albu et al, 2008, p. 25). In this research, a team from the University of Victoria are using CV to detect the states of drivers’ eyes, and if they have been closed for an extended period of time, a possible indicator of sleep, the driver is audibly alerted in an effort to reduce the number of sleep-related car accidents.

**The Purpose**

Understanding that attention is a behaviour that can be learned, and equally, distractibility is a behaviour that can be modified (Meyer & Kornblum, 1993, Dreyfus, 2004), I intend to determine if an eye-tracking, technological-intervention can help students with ADHD. Given
that this thesis is written for a Master’s level degree, and since, according to the literature review, this type of technological intervention had not yet been attempted, the first hurdle was to determine if an app could be programmed to accurately capture the students’ attention and distractions. This makes the app development a proof-of-concept process in an effort to answer the research questions.

Integrated into today’s smartphones and tablets are forward facing cameras that, for the majority of the device’s use, lay dormant. By using the integrated cameras and Open-CV software, the user’s eye movements can be captured and analyzed, providing for a relatively cost-effective research tool. Instead of measuring one, many, or all of the four basic types of eye movements, as mentioned previously, as suggested by Ross et al (2000), and since this research is specifically for ADHD students, I propose to take the measurements one level up; use the combination of the four basic types of eye movements to learn the students’ eye movement habits of attentiveness and distractibility. In doing so, I am not concerned with the minor movements of the eyes, but rather with the combined results of the students’ eye movements.

**Theoretical Framework**

There are two core theories that underpin and support this research: behaviourism learning theory (Bandura, 1962; Tolman, 1932; Watson, 1913; Pavlov 1901) and the resulting, operant conditioning theory (Hull, 1952; Skinner, 1938; Thorndike, 1898). Attention, or lack thereof, and distractibility are simply behaviours. Understanding that humans can, and often do, learn through behaviour observation and/or emulation allows us to better understand how students with ADHD process the surfeit of stimuli presented to them daily. I argue that once an understanding is established, modifying the behaviour by positively reinforcing the good
behaviour and punishing the negative behaviour can be accomplished using operant conditioning theory.

**Behaviourism Learning Theory**

Loosely speaking, behaviourism is an attitude. Strictly speaking, behaviourism is a doctrine. Within the broad scope of behaviourism, there are three different emphases. Some behaviourists argue that the observation of behaviour is the best or most convenient way of investigating psychological and mental processes; this is often referred to as classical behaviourism. Others argue that behaviour itself is the only appropriate subject of psychology, and those common psychological terms (belief, goals, etc.) have no referents and/or only refer to behaviour; this is referred to as methodological behaviourism. Still, others believe that it is in fact the only way of investigating such processes; psychological behaviourism. Those taking this point of view sometimes refer to their field of study as behaviour analysis or behavioural science.

Classical behaviourism, from a psychological perspective, believes that observable behaviour is the only phenomena to be concerned with. It reasons that all psychological functions can be explained in terms of overt, observable and measurable nerve impulses, muscular movements and glandular secretions. The reasoning for this is because observation is required for both objective interpretation and measurement.

Methodological behaviourism is, considered by many to be, “an umbrella term or as the collective term that subsumes a variety of nominally behaviouristic orientations in philosophy and psychology that evolved under the influence of logical behaviourism, analytic philosophy and operationism,” (Moore, J., 2001, p. 234).
Psychological behaviourism, or radical behaviourism, is a research program within psychology. Its rationale is to explain human and animal behaviour in terms of external physical stimuli, responses, learning histories, and reinforcements. Psychological behaviourism is present in the work of Ivan Pavlov (1849-1936) and Edward Thorndike (1874-1949). Its most complete and consequently most influential works is B. F. Skinner’s (1904-1990) work on schedules of reinforcement, which ultimately led to the birth of operant conditioning theory. My research aims to use psychological behaviourism as one of its underlying theories.

**Operant Conditioning Theory**

First discovered and published by Jerzy Konorski (1903-1973), and later expanded upon by Edward Thorndike (1874-1949) and B.F. Skinner (1904-1990), operant conditioning, otherwise known as instrumental conditioning, is a type of learning in which an individual’s behaviour is modified by its antecedents (predecessors) and consequences. In layman’s terms, this means that good behaviour, or the behaviour that we are looking for is rewarded, or reinforced, while bad behaviour, or the behaviour we are looking to eliminate, is punished. For both reinforcement and punishment, the fundamental tools of operant conditioning, there are positive and negative implementation approaches. Positive has a stimulus delivered following a response, where negative has the stimulus removed following a response. These combinations create four basic consequences: Positive reinforcement, negative reinforcement, positive punishment, and negative punishment. Additionally, there is a fifth consequence called extinction. Extinction occurs when a previously reinforced behaviour is no longer reinforced. Given the time constraints of this research, it is undoubted that extinction will take place post-study, and as such will be discussed in the limitations and delimitations section.
Since the two main goals of this technological intervention were to increase attentiveness and decrease distractibility, I employed both reinforcement and punishment. Attentiveness was one of the behaviours I was looking to increase, and as such, it was rewarded while distractibility, being the behaviour I wished to decrease, was punished. Although the implementation of the methods will be described in detail at a later point, it is important to acquire a basic understanding of how the technology intervention worked and how it employed these theories.

Method

As mentioned, the methods and methodology will be discussed later on, but to provide insight as to how these theories were used, it is important to understand, at least superficially, how the technological intervention worked. This technological intervention was created in the form of an application running on tablets and smartphones with front-facing cameras. The application monitored and stored data related to the students’ eye movements using the camera, first to learn their attentiveness and distractibility, then after a pre-determined time, to deliver the intervention. As the application learned the students’ eye-movement patterns, or habits, it did so by using psychological behaviourism. When the application moved into the intervention phase, it used information learned in the previous phase rewarding the student for increased attentiveness. The reward was in the form of levelling up. Once the student had achieved the desired attentiveness, they would increase or move up one level, initially starting at level one. In other words, the application introduced an appealing stimulus (the increase in level) in response to the student’s attentiveness, or positive reinforcement. In contrast, when the students’ attention had been lost, the application made the screen flash and emitted a harsh buzzing noise, introducing an unpleasant stimulus, or positive punishment.
Problem Statement and Research Questions

In my reviews, I have discovered there are many papers, articles, and books covering the phenomena of ADHD. I have also found, as discussed earlier, there have been studies published surrounding tracking eye movements in children with ADHD, however, they either did not specifically include students with ADHD in their measurements or the measured and compared a single type of the four basic eye movement types; for example, SPEM. My research, by making the measurement one level higher and combining all of the four basic types into patterns or habits, much like Pavlidis, recorded data related to attentiveness and distractions as it related directly to students with ADHD, in response to the question: What benefits can an eye-tracking technological-intervention designed to increase attentiveness and reduce distractibility provide elementary school children ages six through thirteen with ADHD? Additionally, it specifically tried to answer:

1. What feedback can eye-tracking technologies provide students diagnosed with ADHD in order to improve their attentiveness and distractibility?
2. What additional benefits, such as self-esteem and transferability, can be realized using this technological intervention?

Importance of the Research

With nearly 11% of students aged 4-17 with ADHD (CDC, 2012), and a further 5% per year being diagnosed annually in the United States (CDC, 2012), ADHD is a very relevant problem affecting an ever-growing population of students. Distractibility is a common issue for students with ADHD; however, attention is a trainable skill (Meyer & Kornblum, 1993). Given that attention is a skill that can be acquired (Dreyfus, 2004), children with ADHD should be able
to learn that skill, and this is what my research endeavoured to establish. In measuring
distractibility, Blakeman (1999) underscores the need for consistent distractors but admits that,
“previous research has yielded inconsistent findings related to distractibility in ADHD,” (p. iv).
Sue Haynes, in her 2007 book, Creative Mavericks: Beacons of Authentic Learning suggests
there are multiple ways to stimulate children with ADHD that do not require medications. This
research is important since a portable, hand-held, autonomous behavioural modification app has
not previously been attempted.

**Limitations and Delimitations**

Although ADHD has been generalized to cover all signs and symptoms that could present
themselves, each person afflicted could have any combination of signs and symptoms and at varying levels, making each person unique. This poses additional challenges when determining the limitations and delimitations.

**Scope**

The combined duration of both the technological intervention and the semi-structured interviews was approximately two months. This was comprised of six weeks for the technological intervention portion and an additional two weeks to perform the interviews.

As mentioned earlier, extinction, from an operant conditioning perspective, occurs when a previously reinforced behaviour is no longer reinforced. Gradually, and over time, the previously reinforced behaviour is no longer observable. Given the time constraints of this research, undoubtedly the students taking part would experience extinction of their attentiveness behaviours once the technological intervention had concluded. Unfortunately, this was unavoidable in the time-frame allotted.
Inclusions

I anticipated requiring approximately 36 participants for both the qualitative and quantitative portions of the study. This number was comprised of 12 elementary school students and their parents (approximately 24). The 24 parents were an approximation because elements such as marital status were not known at the time volunteers were being recruited.

Only the 12 students were to be involved in the technological-intervention, quantitative portion of the study, while both the students (12) and parents (approximately 24) would be involved in the semi-structured interview, qualitative portion of the study. Unfortunately, these anticipated numbers were much higher than the actual numbers and as outlined in the information management section, some of the data had to be excluded. This is discussed in more detail in the next section.

Exclusions

Since the purpose of this research was to study the effects technology can have in learning attentiveness for students with ADHD, only students aged 6-13 previously diagnosed with or where the parent(s)/guardian(s) had a strong belief that the student had ADHD were invited to take part. Students without ADHD signs or symptoms and their parent were not invited to participate since including these students in the research would contaminate or skew the data, making it potentially misleading and less actionable. Additionally, students beyond the age of 13 have already began to create their own coping mechanisms which could have also adversely affected the data, making it less actionable, and as such, were eliminated from this research.
As mentioned earlier, the actual number of participants fell considerably short of the anticipated number of participants. Of the 12 families that expressed interest in participating in the research, only 10 made themselves available to sign the free and informed consent forms. Of those 10, only six managed to install the software. The remaining four declined my repeated attempts to help them install the app. Of the six that managed to install the app, two dropped out mid-way through the intervention. One became too frustrated with the problems with the app and quit, and the other had a tantrum and his parent removed him from the intervention. This left four participants that completed enough of the technological intervention that a reliable trend line could be established.

**Definition of Terms**

**BSD License:** The BSD license is a class of extremely simple and very liberal licenses for computer software that was originally developed at the University of California at Berkeley, allowing for redistribution without restrictive licensing.

**Computer Vision (CV):** “Computer vision is the science of endowing computers or other machines with vision, or the ability to see,” (Learned-Miller, 2011, pg. 2).

**Diagnostic and Statistical Manual of Mental Disorders (DSM):** “The standard classification of mental disorders used by mental health professionals in the United States. It is intended to be applicable in a wide array of contexts and used by clinicians and researchers of many different orientations (e.g., biological, psychodynamic, cognitive, behavioural, interpersonal, family/systems),” (APA, 2014)
OpenCV: “OpenCV (Open Source Computer Vision Library) is an open-source BSD-licensed library that includes several hundreds of computer vision algorithms,” (OpenCV Dev Team, 2014).

Chapter 2 – Literature Review

As discussed in the importance of the research section of the background to the study chapter, the prevalence of ADHD makes it “among the most common behavioural disorders among children,” (Stern & Shalev, 2012, pg. 431). Although not classified as a learning disability (DSM-IV, APA, 2000), ADHD and its associated attentional deficits can cause reading comprehension issues. Indeed, ADHD is highly comorbid with reading disabilities (RD) (Antshel et al., 2011; Germano et al., 2010; Kelly, 2009), with over 80% of children with ADHD and 60% of children with RD meeting the criteria for at least one additional diagnosis, (Willcutt & Pennington, 2000a, 2000b). These reading comprehension issues can translate into poor academic achievement and these characteristics will continue to manifest in high school and post-secondary school (Stern & Shalev, 2012; Weyandt & DuPaul, 2008). Understanding how ADHD relates to reading comprehension deficits allows for proper use of learning theories coupled with technology to design and deliver an effective intervention.

Learning theories affect our everyday life. It could be argued that, when stopped at a traffic signal and contemplating on the day’s events, you are in the reflective observation stage of Kolb’s cycle of experiential learning (Kolb, 1984).

Technology is advancing at an exponential rate and the affordances it provides and will provide have not yet been fully realized. Recent advances in camera accuracy and programming tools are allowing for research to be performed in areas it was not previously thought of.
None of the literature reviewed showed where a similar technological intervention had been attempted. This became problematic since there was no existing literature to support that my idea was feasible. This meant that to keep my research grounded, I would have to research and review literature from three separate topic areas and show how they interrelated. To allow for a clearer understanding of where my research exists in relation to the literature reviewed, it is best viewed as a Venn diagram as follows:

Figure 1

In an effort to triangulate existing research around my subject area, the technological intervention for students with ADHD as noted in figure 1, it will be necessary to break it into three distinct topics as shown in figure 1, above: Reading comprehension and ADHD, learning
theories, and technology. Given the disparate nature of the reviewed literature, and to provide context to the studies being reviewed, the format generally begins with an explanation of the research followed by how it influenced my research.

**Reading Comprehension and ADHD**

The overarching goal of this topic is to show the relationship between reading comprehension, ADHD, working memory (WM), and the common variable to all three; attention, or lack thereof. Given the broad topic area of reading comprehension and ADHD, it is necessary to break it into subtopics, a logical process if you will, to further narrow existing literature to better frame my research. The subtopics start with a discussion around the difficulties in reading comprehension and how these are common in students with ADHD. The next subtopic shows how reading comprehension has been linked to WM. The following subtopic discusses how students with ADHD have been shown to have deficits in WM. The fourth subtopic shows that attention control is an important component of WM capacity. The fifth and final subtopic discusses how WM deficits can be overcome.

**Reading Comprehension**

Efficient reading comprehension is an important skill that underlies academic achievement. In their 2011 study, McGrath et al. studied 614 children and adolescents (386 males and 228 females) aged 8-16 years and tested a multiple cognitive deficit model of RD, ADHD, and their comorbidity (neurodevelopmental disorders). The goal of the study was to determine if employing a multiple cognitive deficit model could identify the shared predictor for RD and ADHD comorbidity. A battery of tests was used to test the students’ single word reading, verbal working memory, processing speed, and naming speed constructs. The model
suggested that phonological awareness was an accurate predictor of RD and response inhibition was a unique predictor of ADHD. By using the multiple deficit model, “the residual correlation between RD and inattention was reduced to non-significance,” (McGrath et al, 2011, pg. 554), indicating that of the three shared, cognitive variables modeled, naming speed and verbal working memory do not demonstrate unique and consistent relations with RD and ADHD. This meant that the only shared predictor, processing speed, could account for their comorbidity. The concept that inattention is a singular entity is naïve, given the literature available and as discussed below, and discounting it without fully understanding it uncovers some doubt in the multiple cognitive deficit model and/or McGrath’s implementation. This research remains relevant to mine however, since it shows that there are other possible predictors to RD/ADHD comorbidity and strengthens the relationship between ADHD and reading comprehension deficits.

In contrast to the work of McGrath et al., Stern and Shalev (2013) reiterate that attention is "a multifaceted system composed of several different attention networks" (Tsal et al., 2005, pg. 432). By understanding there are many different types of attention allows researchers to better understand why different students with ADHD show different combinations of attentional deficits. Tsal et al. (2005) outlined four attentional subsystems (or functions): Orienting of attention, selective attention, sustained attention and executive attention. After testing their 40 participants (20 with clinically diagnosed ADHD, and 20 normal functioning participants) they determined that the only significant difference between the ADHD group and the control group was in the sustained attention task. They concluded that “difficulties in reading can derive, among other things, from impaired sustained attention” (Stern & Shalev, 2013, pg. 439). This
research is important because it reinforces my proposed study in that I am trying to increase attention in students with ADHD, as per the research question.

**Links to Working Memory**

Working Memory (WM) is the system that actively holds multiple pieces of temporary information. It is here that manipulation of the temporary information can take place. WM capacity refers to the number of items that can be recalled during a complex WM task. At the core of WM, it is generally accepted (Garcia-Madruga et al., 2013; Rogers et al., 2011; Unsworth & Engle, 2007; Baddeley, 2000; Cowan, 1999; Baddeley & Hitch, 1974) that there is a central or executive processing unit “whose main functions are to focus and switch attention, to activate and update representations, and to inhibit automatic processes and discard irrelevant information,” (Garcia-Madruga et al., 2013, pg. 41). In their 2014 study, Garcia-Madruga et al. found that reading comprehension abilities were very closely related to the executive processes; these same executive processes students with ADHD have problems with (Antshel et al., 2011). The Garcia-Madruga et al. study shows that reading comprehension is directly related to the executive processes of WM. This relationship, specifically in students with ADHD, is important to my research as it will be used later to show that students with ADHD are able overcome WM deficits.

In a complimentary study, McVay and Kane (2012) tested the theory that attention control underlies the predictive relationship between WM capacity and reading comprehension. They tested 242 students on various tasks to determine if mind-wandering, or task-unrelated-thoughts (TUT) had any effect on WM capacity and/or reading comprehension. They found that, “individuals’ TUT rates, representing failures to maintain on-task thoughts, were stable across both attention-control and reading tasks, and this general susceptibility to off-task thought was
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The two studies above show a direct relationship between WM, attention control, and reading comprehension, and have direct relevance to my research in that attention control, or one’s ability to maintain attention, is the very item my research question attempts to answer.

ADHD-WM Deficits

As alluded to earlier, students with ADHD suffer from increased WM deficits. There is substantial evidence indicating that WM plays a pivotal role in the development of academic skills (Rogers et al., 2011; Antshel et al., 2011; Alderson et al., 2010), and as such, students with ADHD are at a greater risk of poor academic performance (Stern & Shalev, 2012; Weyandt & DuPaul, 2008).

Consistent with developmental research, the 2011 study by Rogers et al. investigated the relationship between behavioural inattention and WM and how it directly affects academic achievement. As children age, changing to adolescents and to adults, their WM processes undergo drastic changes. For children the WM type is primarily visual encoding. As they age and move through middle-school, they move into combined visual-verbal strategies then finally into high-school and more adult-like, auditory-verbal working memory (Rogers et al., 2011). Understanding this change in WM supports my research. Given the age group I planned to study, I was most concerned with the visual encoding use of WM and how the proposed technological intervention uses this knowledge.
Building on a number of previous meta-analytic studies, (Willcutt et al., 2005; Martinussen et al., 2005) as they related to WM deficits and attentional control, Kasper et al. (2012) included 40 additional studies, for a total of 45, that were not previously included in other meta-analytic studies. Their analysis concluded that there is compelling evidence to indicate that ADHD-related hyperactivity, inhibition deficits, social skills deficits, and more importantly to my research, attention deficits are, “predominately attributable to [central executive] CE processes,” (Kasper et al., 2012, pg. 613). The relevance of this research is important because of the number of studies reviewed, and as such the number of involved participants reaffirms that students with ADHD suffer from increased WM deficits.

Attention Control

It has been established that, “evidence from ‘executive’ tasks suggest that WMC [capacity] is closely linked to attention control,” (McVay & Kane, 2012, pg. 304). Biologically, the neurotransmitter dopamine and the dopaminergic receptors play an important role in understanding ADHD (Hodgkins et al., 2012). Dopamine is a naturally-occurring stimulant, which in students with ADHD is lacking or deficient. Additionally, or consequently, the prefrontal cortex, with its high requirement for dopamine also plays an important role. It is in the prefrontal cortex that higher cognitive functions, such as the executive processes of WM are performed. “The prefrontal cortex has many reciprocal connections with other brain regions, including the striatum (caudate nucleus, putamen), cerebellum and parietal cortex. Research has indicated that some of these brain regions are slightly smaller or have decreased activation in people with ADHD,” (Ramachandran, V. S., 2011). With slightly smaller sizes or decreased activation of these brain regions, students with ADHD are biologically predisposed to inattentiveness. Through the use of other stimulants, such as amphetamines, dopamine
production in the brain can be augmented providing students with ADHD a respite from their inability to control attention (Hodgkins et al., 2012).

**Overcoming WM Deficits**

Generally, there are two ways individuals with ADHD can enhance their WM performance: psychostimulant medication, such as methylphenidate or dexamphetamine, or by intensive WM training (Holmes et al., 2010). My research, being more concerned with learning attention, which as examined can adversely affect WM as it directly affects executive processing, will only deal with the non-pharmacological, although medication information was solicited from the participants for comparison purposes with those not taking medications.

In 2010, Holmes et al. conducted a study in which they evaluated both psychostimulant medication and WM training in 25 children (21 boys, 4 girls), aged 8-11 years, all having been formally diagnosed with ADHD and all taking one form of psychostimulant medication. These children were asked to use the Cogmed Working Memory Training, (Cogmed, 2014), for an average period of 23.72 school days. Prior to the Cogmed training, all participants were asked to stop taking their medication and at that point, were cognitively assessed. Just prior to, and while taking their medication, during and after the Cogmed training the students were tested using a number of tests aimed at evaluating the efficacy of the Cogmed training. They concluded that although psychostimulant treatment had significant increases in WM performance, it was not as generalized as was the Cogmed training in that psychostimulants only affect certain parts of the brain (Holmes et al., 2010; Roche & Johnson, 2014).

Although similar to the Cogmed product in that my application had a reward structure (positive reinforcement), the manner in which those rewards were dispensed was based on the
student’s attentiveness to the device and not on the completion of the activity. Additionally, my application included a punitive system (positive punishment) in which the students were warned of their distractions.

**Learning Theories**

The purpose of the learning theories topic is to explain what theories best suit both design and delivery of the technological intervention, based on what has been explained in the reading comprehension and ADHD topic. Just as the reading comprehension and ADHD topics were too broad to review in their entirety, so are learning theories. Therefore, it is necessary to break them down into four sub-categories: Attention is behaviour, behaviour modification, operant conditioning (OC) and ADHD, and learning theories and technology.

**Attention is Behaviour**

Attention is the cognitive and behavioural process of selectively concentrating on one aspect of the environment while ignoring other things (Anderson, 2004). Given that attention is behaviour, it can be learned. To study this in as close to a natural state as possible, and to eliminate medication interference, Prins et al. (2011) studied 52 students aged 7-12 years who were on a waiting list for ADHD treatment. Part of their inclusion criteria was no use of medication on days of training to mitigate that risk. This study sought to understand whether video game elements would enhance motivation and training performance and efficacy in students with ADHD. Their method was essentially a gamified set of WM training exercises delivered via laptop. They found that children with ADHD performed better interacting with the laptop than with traditional methods and that they were more attentive to the computer screen.
and for longer periods (Prins et al., 2011), which reaffirmed previous research by Holmes et al., (2010) and Ota et al. (2002).

In complimentary fashion, Mana & Mich (2013) studied the effects of attention capturing through interactions and stimuli. “High technology and computer software applications with appropriate interfaces can offer valuable ways to capture attention while doing an e-learning task,” (Mana & Mich, 2013, pg. 436). They employed face-tracking software, and using a web camera attached to a computer, were able to determine not only if the student was attentive, but based on facial expressions, their engagement according to their emotional state.

The two previous studies show that attention is behaviour, and as such it can be learned. In the next subtopic, behaviour modification, I discuss different ways behaviour can be modified.

**Behaviour Modification**

Understanding that attention is a cognitive and behavioural process, through the use of a technological intervention, negative behaviours can be replaced with positive ones. There are many ways behaviour can be modified. One way that is becoming more popular is through the use of behavioural intervention technologies (BITs). “BITs apply behavioural and psychological intervention strategies by using digital media to target behaviours, cognitions, and emotions in support of physical and mental health,” (Scheuller et al., 2013, pg. 478). There are a number of advantages to be had using BITs, state Scheuller et al. (2013). One of these advantages is how deeply BITs can be integrated into daily life, but to be deeply integrated into someone’s life, the person has to want to use it extensively. These BITs need to be unobtrusive, reinforcing, aesthetically pleasing, trustworthy, and provide acceptable levels of privacy (Scheuller et al., 2013, Consolvo, et al., 2009; Montague et al., 2009). “Teaming psychologists with experts in
technology will help to promote novel interventions rather than using technology to disseminate existing treatments,” (Scheuller et al., 2013, pg. 478). This research was of great importance to my own since the application is in fact a BIT, and the results of this study guided the design of and depth of integration in my application.

In 2009 Fabiano et al. conducted a meta-analysis of behavioural treatments for ADHD, concluding that, "across study designs and including different settings (e.g., home, school, recreational), a consistent pattern of results emerged – behavioural treatments improve the functioning of children with ADHD,” (Fabiano et al., 2009, pg. 136). Indeed, these conclusions are echoed in the 2014 study by Hodgson et al., where they replicated and expanded on Fabiano et al.’s 2009 study and found that behaviour modification and neurofeedback treatments were most supported by their results. Neurofeedback through the use of an electroencephalograph (EEG) is a form of operant conditioning (OC) and as such will be discussed in the next subtopic. Again, this research was of great importance to my own in that not only does my application modify behaviour, it does so by employing OC.

**OC and ADHD**

The cornerstone of behaviour modification has to be OC theory. An evolution of behaviourism learning theory (Bandura, 1961; Watson, 1913), operant condition theory uses negative and positive reinforcements and punishments to change inappropriate behaviour into more acceptable behaviour (Skinner, 1974; Thorndike, 1927). OC, by means of neurofeedback, has been found to be a very effective treatment for ADHD (Loo & Makeig, 2012; Nazari et al., 2011). Neurofeedback is a form of biofeedback that uses EEG to show, in real time, the brainwave activity of the subject in question. This allows the individual to see and control their brainwaves, with either positive feedback given for desired brain activity or negative feedback
given for brain activity that is undesirable, usually in the form of audio or video. This OC allows the ADHD student, over time, to modify his/her brainwaves in a positive manner, (Hillard et al., 2013; Loo & Makeig, 2012; Nazari et al., 2011). Granted, some may say that neurofeedback is controversial and lacking methodologically however, the above named authors had their articles published in reputable, peer-reviewed journals.

In contrast to the Cogmed product where only a reward is available, and only at the end of the activity, my application employed the operant conditioning tools of positive reinforcement and positive punishment to deliver immediate feedback through the device, adhering to a strict timing structure. Research has indicated that reinforcement strategies such as reward, punishment/response cost, and accuracy feedback, or combinations thereof, have a positive impact on both task performance and motivation in all children, not only those with ADHD (Prins et al., 2011). This effect “is somewhat more prominent in children with ADHD: the high intensity of reinforcement appeared highly effective in ADHD, and children with ADHD prefer immediate over delayed reward” (Prins et al., 2011, p. 115).

As shown above, students with ADHD respond well to behavioural modification. They are also able to learn how to modify their brainwaves in response to stimuli, either positive or negative. This means my research was perfectly situated since the app attempted to modify behaviour using positive and negative stimuli.

**Technology**

As technology evolves, it allows us to use it in more and varied ways. As discussed in the previous topic, learning theories, the technology of EEG has been used for many years in the diagnosis and treatment of ADHD. This topic delves into new and emerging technologies by
breaking it into three subtopics: Eye-tracking, eye-tracking in research, and open-source computer vision (OpenCV).

**Eye-Tracking**

Eye tracking capabilities can vary from simple facial recognition (Mana & Mich, 2013), to very granular saccadic – even micro saccadic, smooth pursuit eye movements (SPEM), vergence, and vestibulo-ocular measurements (Fried et al., 2013; Bayram et al., 2012; Pavlidis, 1985). Eye-tracking technology has been used for everything from better understanding dyslexia (Hatzidaki et al., 2011) to components of architecture and display composition and placement in retail shopping experiences (Harwood & Jones, 2013). The “information conveyed by eye movement data is considered a direct measure of the locus of the user's (visual) attention,” (Mana & Mich, 2013, pg. 436). Understanding how and what eye-tracking technology tracks was extremely important to my research as it informs what technologies were best suited to answer my research questions.

**Eye-Tracking in Research**

There have been numerous studies using eye-tracking technology (Mana & Mich, 2013; Fried et al., 2013; Wong et al., 2012; Bayram et al., 2012). In fact, there have been numerous studies in the same knowledge area focusing on driver safety (Budiharto et al., 2013; Pimplaskar et al., 2013; Abtahi, 2012; Flores et al., 2010). These studies all share the use of eye-tracking technology to test drivers’ drowsiness by studying various facial states, eye-closed for longer than a blink (Flores et al., 2010), yawning (Abtahi, 2012), and others.

Another example of different ways eye-tracking can be used in research is shown in a study by Kim et al. (2013). Their study also relates back to the topic of reading comprehension
as it used eye-tracking technology to measure reaction and gaze times for graph comprehension in dyslexic students. In this study the students were seated at a specialized terminal using a specialized camera system to track both eyes simultaneously. This level of specialization would defeat the idea of portability in my application and therefore, does not directly apply; however, their study is yet another example of the effectiveness of eye-tracking in research.

**OpenCV**

One of the concerns with eye-tracking software is its accuracy. This can be especially challenging when using the front-facing cameras found in most tablets and smartphones. In a study published in 2013, Budiharto et al. developed a drowsiness detection system using OpenCV and an Android mobile device. In their implementation, they used the front-facing camera of the mobile device to detect a driver’s state of awareness. They concluded that the accuracy of the front-facing camera was sufficient to detect eyes and their attention to the road. This was of importance to my research since it affirmed that front-facing cameras have the granularity and accuracy to track the attention of my subjects and ultimately achieve my research goals.

Using OpenCV provides a number of advantages. The foremost of these is cost. Being open-source there are no costs to license the development software. Additionally, there are freely-available libraries of code examples. Since the programming of the application in my study was outsourced to an external developer, programming costs were reduced as a result of these libraries; the programmer did not have to create new code and could simply copy and paste most of what is required.

**Summary**
As we have read, students with ADHD have reading comprehension and WM deficits as a result of their lack of attentional control however these attentional deficits can be overcome as exampled in the discussion on WM. Since attention is behaviour, and we know that behaviour can be modified, I argue that OC and more importantly, that technological interventions employing OC work extremely well. Armed with this knowledge, a better understanding of what eye-tracking is, what it measures and how well it measures it can be gained. Finally, given the budgetary constraints on this research, cost-friendly alternatives, such as OpenCV, were reviewed to ensure their abilities would be sufficient to effectively deliver and monitor the intervention.

Chapter 3 – Methods and Methodology

Methodology

Mixed Methods Research

The data collection component of the research began with a survey, gathering predominately demographic and medication information. This survey was self-administered at the individual’s home and was included in the call for volunteers hand-out (please refer to Appendix A). This survey contained both calculable, numeric values, as well as free-text as a result of open-ended questions. Once volunteers for the study had been established, and had signed the free and informed consent form (please refer to Appendix B), the technology-based quantitative study began. All of the data collected here were calculable and numerical. Following the quantitative data collection period, a qualitative, semi-structured interview was scheduled with all the participants (please refer to Appendix C). Since the majority, if not all, of the questions are open-ended, the data collected were analyzed qualitatively. Therefore, the
methodology for my research was to be mixed; that is to say it contained both quantitative and qualitative studies.

**The Right Choice**

The choice to make this research mixed methodological research was determined by the differences in the data to be collected. The intent for mixing quantitative and qualitative research designs is to maintain the strengths and ameliorate the weaknesses in both designs (Creswell, 2012; Caruth 2013; Greenwood, & Terry, 2012; Truscott et al., 2010; Venkatesh et al., 2013). The quantitative portion of the research, which is arguably the larger of the two, dealt only with statistical variances and therefore only satisfied some of the research questions but not all.

Since I was looking at uncovering the additional benefits that could be realized using this technological intervention, I needed to move beyond the statistical analysis and dig deeper into the emotions and feelings of the participants. Typically, it is accepted that a greater depth of understanding of the study is generally gained by qualitative research than by quantitative (Caruth, 2013; Lund, 2012). By combining the two paradigms I could ensure reliable, valid, and generalizable results are gleaned through the use of triangulation.

Indeed, “Using triangulation as a methodological metaphor can facilitate the integration of qualitative and quantitative findings and help researchers to clearly present both their theoretical propositions and the basis of their results. Using triangulation as a methodological metaphor may also support a better understanding of the links between theory and empirical findings, challenge theoretical assumptions and aid the development of new theory,” (Östlund et al., 2010, pg. 370). This means that, not only does triangulation help me to present my findings
to the reader in a clearer and more concise manner, it fully explores the knowledge area opening the possibilities of using this knowledge towards existing problems in relatable areas.

Venkatesh et al., (2013) described seven purposes for mixed methods research: Complementarity, completeness, developmental, expansion, corroboration/confirmation, compensation, and diversity. The purposes are described as follows:

(1) Complementarity - to obtain mutual viewpoints about similar experiences or associations.
(2) Completeness - to ensure total representation of experiences or associations is attained.
(3) Developmental - to build questions from one method that materialize from the implications of a prior method or one method presents hypotheses to be tested in a subsequent method.
(4) Expansion - to clarify or elaborate on the knowledge gained from a prior method.
(5) Corroboration/Confirmation - to evaluate the trustworthiness of inferences gained from one method.
(6) Compensation - to counter the weaknesses of one method by employing the other.
(7) Diversity - to obtain opposing viewpoints of the same experiences or associations

(Venkatesh et al., 2013, p. 26). All seven of the aforementioned purposes applied directly to my research, so by simple association, my research was mixed methods research.

Methods

Given the merits of both qualitative and quantitative methodologies and how they both can be used to compliment each other to provide a better understanding of the data, I chose a mixed-methodology. I chose to sandwich the quantitative portion between two qualitative
portions. The first qualitative portion was the initial survey included with the call for volunteers. The quantitative portion, or the technological intervention, tracks and records statistical data and also acts as the delivery mechanism for the operant conditioning. The final part of the qualitative portion was the semi-structured interview. Additionally, and because it was assumed that there were direct relationships between the qualitative and quantitative data, a case-study approach was used.

**Call for Volunteers Survey**

The call for volunteers was just that; a plea for participants in my research (please refer to Appendix A). Part of this letter, handed out by a certified ADHD counsellor, were some survey questions, mainly quantitative in nature, gathering demographic and medication-history information. The certified ADHD counsellor handed the letter to those students and parents he was counselling, indicating the student was already diagnosed with ADHD or his/her parent(s)/guardian(s) had a strong belief that the student had ADHD. At this point the onus was on the parent(s)/guardian(s) to contact me, and if there was interest, we would arrange a meeting where I clearly outlined and discussed the study, laying out all the information the participants required to make free and informed consent culminating in the signed Free and Informed Consent form (please refer to Appendix B).

**The Technological intervention**

The quantitative method, was based on using the application. The application performed like a shell, in which a web browser was opened, allowing the students to navigate to a relevant, curriculum-based testing website, without having them realize that their eye movements were being tracked. The advantage of designing the application in this manner is that it allowed any
website to be enhanced by the eye-tracking application, eliminating the need to develop additional curriculum for data collection and testing purposes.

For the first phase, which was seven days, the application tracked and stored information such as the start time of the distraction and the end time of the distraction thereby, allowing the software to calculate distraction duration (end time – start time = distraction duration) and attention duration (start time (current distraction) – end time (previous distraction) = attention duration). From these calculations it learned both the students’ attentiveness and distractibility, and over time, calculated an “attentiveness quotient” (AQ) and a “distractibility quotient” (DQ) using a carefully crafted algorithm. These became the baseline AQ and DQ.

Once the student’s AQ and DQ were known, the software began phase two of delivering the intervention for a length of 28 days. Through the use of positive reinforcement, when the student’s attention to the device was longer than that AQ, the student was rewarded in the form of levelling up. Through the use of positive punishment, when a student’s gaze moved away from the device longer than the DQ, the device began flashing the screen and making an irritating buzzing noise, in an effort to regain the student’s attention, bringing the student back on task. Once the student’s attention had been reacquired, the negative stimulus was removed and the participant could continue with his or her test. Over time, the duration between the attentiveness and reward was increased and the duration between the distraction and the distraction counter-measures was continually decreased.

A final stage, again seven days, had the application re-learn the AQ and DQ. These values were compared to the baseline AQ and DQ to see if there is a change in the individual’s behaviour.
Although I do have a background in application development, I did not do any of the code-writing. The success of this research depended heavily on the success and functionality of the application and I would not risk those requirements on my code-writing abilities. Instead, I used my extensive background in software architecture to design the application and my experience in hiring and managing off-shore development companies to hand the code writing off to a freelance contractor. The engagement with the contractor was done through the freelance contractor portal at odesk.com, and all payments to the contractor were made through same.

**Post-Technological intervention, Semi-Structured Interviews**

In follow-up and complimentary to the technological intervention, I had semi-structured interviews with all of the participants. The goal here was to use these interviews to uncover data that were not necessarily available from the quantitative-only study. Through the use of leading questions in the areas of behavioural changes and attention and distractibility changes, my hope was that these interviews showed that there was an increase in attention, and that increase had additional positive effects.

One positive effect I had hoped to discover was an increase in self-esteem. As part of the ADHD disorder, most people who are affected have less than average reading skills; they avoid public speaking and reading aloud and they feel self-conscious about their abilities, driving down their self-esteem, (Klassen et al., 2004, p. e542). If there was to be a positive result from the technological intervention, namely, an increase in attentiveness and a decrease in distractibility, I was confident that the interviews would discover that the students felt more confident about their ability to control their attention, and in turn, better about them.
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**Case Studies**

Given the low number of participants that completed the technological intervention, and to ensure reliability between the two paradigms, a case-study format was chosen to not only report the data and analyses, but to delve deeper into the effectiveness of the research. “A hallmark of case study research is the use of multiple data sources, a strategy which also enhances data credibility” (Baxter & Jack, 2008, p. 554, Patton, 1990; Yin, 2003). To this end, the post-technological intervention semi-structured interview questions, the qualitative portion, were designed in such a way as to illicit honest emotion and feelings that could be directly related to the technological intervention, or the quantitative portion.

**Data Analysis**

Given the mixed-methodological approach I chose and the fact that there was both qualitative and quantitative data collected, different methods of analysis needed to be employed.

**Qualitative**

Given the case-study approach used, different types of qualitative analysis were needed. The first of these were the individual case-studies where data specific to the participant was reviewed. It was during these analyses that the variances between the quantitative and qualitative data were reconciled. Ellen Taylor-Powell and Marcus Renner outline a five-step process in their article, *Analyzing Qualitative Data* (2003):

1. Get to know your data
2. Focus the analysis
3. Categorize information
4. Identify patterns and connections within and between categories
5. Interpretation—Bringing it all together

Once the individual cases had been thoroughly analysed individually, they were re-analysed in an aggregate form. The second analysis began by reading all of the data to first familiarize myself with the data, then by reading it a second and third time, during which reads I coded the data into themes and sub-themes. This allowed for matching, grouping, and categorizing common themes and sub-themes together in an effort to bring it all together and satisfy the research questions, as mentioned in the methodology section above.

Quantitative

The quantitative analyses were performed in two distinct areas for separate reasons. The first area was the quantitative analysis that was performed within the application during phase one, allowing the application to calculate the AQ and DQ prior to the intervention, delivered in phase two. The calculation at this point allowed the application to capture a baseline of the students’ attentiveness and distractibility habits prior to the intervention. These calculations incorporated averages of all values collected during phase one and distilled them all into two decimal values; one each for AQ and DQ. Additional calculations were to be performed during phase three of the technological intervention when the application re-learns the AQ and DQ. The intent here was that the calculations at this point would allow the application to capture a post-intervention value of AQ and DQ allowing for a direct comparison to the baseline values mentioned earlier. Unfortunately, none of the participants completed phase three and will be discussed in more detail in chapter five, analysis.

When determining the AQ and DQ a number of methods were experimented with to determine the proper calculations. As the formulas evolved they had to take into consideration
both the measures of central tendency (mean, median, and mode) as well as the measures of variability specifically, standard deviation (Powell, E., 1996, pg. 3-5). Measures of central tendency work very well to characterize what is typical for a group however, uncommonly high or low values can inappropriately skew these measures. To respond to this, the calculations needed to be flexible enough to allow for measures of variability and took into consideration the standard deviation in the data when making these calculations. This is discussed in more depth in the Dependent Measures section, next.

The second quantitative analysis was post-technological intervention using all of the data collected from the application for each individual student. These data were primarily analyzed using scatterplot graphs to show either positive or negative linear tendencies thereby drawing certain inferences.

**Dependent Measures**

To better clarify how the AQ and DQ were calculated, and for complete transparency, their formulas and a discussion of each are provided next. The DQ calculation is the easier of the two; it is simply the mean of all of the recorded distraction durations (see appendix D) for the same period and refer to a central value of a discrete set of numbers specifically, the sum of the values divided by the number of values. Since the intervention used this value when determining when to deliver the reminders, a simple average (mean) was sufficient.

When deciding how the app should deliver the reward, a more robust calculation was required. As discussed above, abnormally high or low values can skew results if only measures of central tendency are used, so to accommodate for this, standard deviation, a measure used to quantify the amount of variation, was introduced into the algorithm to account for measures of
variability. In early calculations using simulated data, it was found that the standard deviation was high, indicating that the data points tended to be far from the mean. To make sure that the participant was able to achieve the reward, only half of the standard deviation was used in the formula, making it: \[ AQ = \text{Mean} + (0.5 \times \text{StdDev}) \].

Ethical Considerations

To properly convey some of the ethical considerations being faced in this research, and to provide additional background information, I will provide some of the concerns and their associated alleviations. To ensure as many concerns as possible are brought to light and to allow an opportunity to discuss how to alleviate said concerns, the following paragraphs will deal individually with those concerns. The areas I was most concerned with were withdrawal of participant, age impediments, information management, and perceptions of power.

Voluntary withdrawal

The participants were informed of their right to withdraw during the free and informed consent phase using same form, as outlined in Appendix C. The participants were reminded twice that they may withdraw at any time with penalty or repercussions. For various reasons, many chose to exercise this right and withdrew.

Under 18

Since 12 of the participants were minors, two signatures were required: one from the student and one from a parent or legal guardian, as shown in Appendix B. Since the parent and child were expected to discuss the research, and the research was explained to them all at the same time, the form had space for both signatures. This allowed each participant to make his/her own decisions.
Information management

For the purposes of this section, it was necessary to combine both the quantitative and qualitative data into a single strategy, since both were stored digitally. Since there were two different types of data, qualitative and quantitative, each will be described as it pertains to the strategy. In this strategy, I will discuss what was being stored and how it was used, who had access to it, and finally, how it was stored.

As mentioned earlier, quantitative data were comprised of times and calculated fields and will be used for data analysis and statistical inferences. Qualitative data were responses to the questions asked during the semi-structured interviews and was used to uncover information that would not have been available from the quantitative data only, and was used to triangulate the data providing for a richer understanding of the effectiveness of the intervention.

Only the researcher and members of the research team had access to the raw data. Should a participant choose to withdraw, any and all data associated with them was destroyed in a timely manner. Any audio recordings of the interviews were immediately destroyed once transcribing had been completed.

The data as a whole, was locally held at the researcher’s home, and was not be stored anywhere in the cloud, be it hosted in Canada, the United States, or any other country; which could have potentially introduced issues related to the Patriot Act or other, similar international laws. To further ensure anonymity, the quantitative data was coded, and only the researcher knew the participants number. The coding key was kept in a separate room in a digital safe with only the researcher knowing the combination.
The qualitative data were collected as recorded audio interviews and was the only media collected. Once the audio recording had been transcribed, the original audio recording was destroyed, and the transcriptions were coded in the same manner as the quantitative data.

Knowing that data were to be transmitted through unsecure email, it was determined that the application would remove any personally identifying information before it created the data file to be sent. This was done by adding the participants code directly in the application. Even if someone was clever enough to capture the emails being sent from the devices, the only data they would see were the distraction start and end times and the calculated AQ and DQ. These data by themselves, meant nothing, protecting the anonymity of the participants.

Perceptions of Power

Performing research with children raises many ethical considerations, one of which is the perception of power or power imbalances (Phelan & Kinsella, 2013, 2011). If the student perceives the researcher to be an authoritative figure, he or she may respond to questions with what they think the researcher wants to hear; to appease the adult. To mitigate this perception, there were no interactions with the child without the parents’ presence. Additionally, any interactions with the child were done in a relaxing environment; the dinner table reminds the student of homework. By using fun, child-like language to ask the questions and provide analogies, the children were more at ease to be themselves.

Chapter 4 – Findings and Analyses

As discussed in the exclusions section, only 4 participants were able to complete enough of the technological intervention to establish a reliable trend line. As such, the results and analyses are reported on a case by case basis. By doing so I am afforded the opportunity to
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report both the quantitative and qualitative results allowing for insightful context necessary in understanding the connections between the two. The coding naming convention used in the cases identifies different components. The Px (where x is a whole number) indicates which participant of the four that had not withdrawn and completed enough of the technological intervention to be included in this review. The code in parenthesis refers to the original code assigned to the participant in the app.

Throughout the technological intervention, the participants were plagued by issues, namely bugs in the app that could not have been corrected before the participants had finished the intervention. These bugs included being punished, or “buzzed”, inappropriately, or at the wrong time, and the rewards disappearing from the screen. Some of the participants indicated that the issues seemed to be incremental or cascading meaning that the issues worsened each day they used it while others indicated that the app functioned properly some days and not others. The unfortunate part of this is that the app recorded distractions when a distraction did not take place; a false-positive. To compound this misfortune, and since there is no way I could differentiate between the actual distractions and the false-positives, there was no way I could clean the data of noise or outliers. For this reason, the data are presented in its raw format, with all calculations using all applicable data. These bugs, although being an annoyance to the participants were few enough to not drastically affect the calculations for the rewards and reminders system of the app.

Before moving into the individual cases, the data, which were emailed nightly from the app in a comma-separated-value (.csv) file, needed to be converted to a Microsoft© Excel™ format, .xlsx for storage, calculations, and charting. An example is shown below:
During the conversion process, the ` character was replaced with a decimal to allow for time calculations to take place. The file name itself contained important data as well, namely which phase the app was in when the data were recorded. This can be seen between the underscores, immediately after the app’s participant code and before the date, in the example file above.

A number of analyses were performed on the data. First, each case was analyzed. In this respect, the quantitative data from the technological intervention was charted and comparisons made. Following that, the qualitative data taken from the semi-structured interview was thematically analyzed to expose common themes within the cases, and finally, both were analyzed together, holistically, in an effort to correlate the data and to possibly discover additional information. Subsequent to the case-level analysis, a higher-level analysis was performed. Since each participant was unique, from an app perspective, each AQ and DQ
calculation is equally unique to the participant. For this reason, the quantitative, technological intervention was not analyzed using aggregate data from each intervention. Conversely, a thematic analysis was performed on all of the data collected during the qualitative portions (the initial survey and the semi-structured interviews) of the study.

**Case 1 – P1 (A-02)**

P1 was a thirteen-year-old boy and was in grade eight at the time of writing. He had not previously been diagnosed with ADHD, yet both parents expressed concerns of attentional deficits. They had no desire to medicate their son and therefore, felt that a formal diagnosis served no purpose. At the time of writing, he had been using computing devices for six years.

**Technological Intervention**

P1 completed five days of phase 1 and ten days of phase 2 of the technological intervention. He did not complete the entire intervention, citing travelling and Christmas holidays as reasons. While participating in the technological intervention, his mother contacted me to indicate the on-again-off-again nature of the issues with the app; some days it would work, and some not. His individual daily results were recorded in the following table:

<table>
<thead>
<tr>
<th>Phase</th>
<th>Date</th>
<th>AQ</th>
<th>DQ</th>
<th>DTT</th>
<th># D</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>11/16</td>
<td>00:21.737</td>
<td>00:58.902</td>
<td>00:26:22</td>
<td>23</td>
</tr>
<tr>
<td>1</td>
<td>11/17</td>
<td>00:50.397</td>
<td>00:06.540</td>
<td>00:25:20</td>
<td>62</td>
</tr>
<tr>
<td>1</td>
<td>11/18</td>
<td>00:18.991</td>
<td>00:06.373</td>
<td>00:19:40</td>
<td>80</td>
</tr>
<tr>
<td>1</td>
<td>11/19</td>
<td>00:21.075</td>
<td>00:10.613</td>
<td>00:25:18</td>
<td>73</td>
</tr>
<tr>
<td>1</td>
<td>11/21</td>
<td>00:13.559</td>
<td>00:09.499</td>
<td>00:19:07</td>
<td>65</td>
</tr>
<tr>
<td>2</td>
<td>11/27</td>
<td>01:11.400</td>
<td>00:01.714</td>
<td>00:07:47</td>
<td>11</td>
</tr>
<tr>
<td>2</td>
<td>11/30</td>
<td>00:59.081</td>
<td>00:01.699</td>
<td>00:14:45</td>
<td>27</td>
</tr>
</tbody>
</table>
Column headers in the preceding table are as follows: Phase indicates which phase the data were recorded for, Date indicates which date the data were recorded on, AQ indicates the calculated AQ for the specific date, DQ indicates the calculated DQ for the specific date, DTT (daily total time) indicates how much time the participant used the app for the specific date, and #D indicates the number of distractions for the specific date. DTT was calculated by using the following formula: Daily End Time – Daily Start Time = DTT. The formula for #D is the total record count. Finally, the calculations for AQ and DQ were discussed in the technological intervention section and are in a minute:second.thousandths format (mm:ss.000). It is important to note that calculated values above are derived from the entire raw data for that particular day. No records were removed and the data were not scrubbed in any way.

Using the raw data from phases one and two, the following calculated results were derived: Phase 1 AQ = 00:27.871, Phase 1 DQ = 00:12.086, Phase 2 AQ = 01:01.166, and Phase 2 DQ = 00:02.296.

**Semi-Structured Interview**

The semi-structured interview took place at a date following the participant’s completion of the technological intervention. The interviews included the participant (P), the parent (mom (M)), and myself, (ME). With the permission of all involved in the semi-structured interviews the sessions were audio recorded for easier transcription. In accordance with the information
technology section the audio recordings were destroyed once transcription was completed. To gain a better understanding of the data in its entirety the un-edited transcript as well as my thoughts and observations recorded during the interview are provided in appendix F.

Immediately prior to the interview, the results from the technological intervention were discussed and explained. At the outset of the interview the participant seemed very at ease yet ready to answer any questions I posed him. Mom sat away from myself and the participant and I was concerned that she was not going to answer any questions during the interview.

**Technological Intervention Analysis**

As mentioned, P1 completed five days of phase 1 and ten days of phase 2. The results recorded in table 1 were plotted in a scatterplot-formatted graph, shown in Figure 2:

Figure 3
Following is a brief explanation of the graph components. The X axis are dates with the Y axis being time duration in a minute:second.thousandths format (mm:ss.000). The data points are the AQ calculations, represented by diamond-style markers, and DQ calculations, represented by circle-style markers, for that specific date. The black connecting-line represents the connections between the AQ data points and the grey connecting-line represents the connections between the DQ data points. The dotted black line indicates the trend for the AQ if the intervention were to continue and the dotted grey line indicates the trend for the DQ if the intervention were to continue. Trendlines are included for informational purposes only and are calculated to reveal a linear relationship between two variables, $x$ and $y$, in the $y = mx + b$ form. To calculate this, we need to know slope ($m$) and offset ($b$). Slope is calculated using this formula:
ON-TASK: INCREASING ATTENTIVENESS IN STUDENTS WITH ADHD

\[ m = \frac{n \sum(xy) - \sum x \sum y}{n \sum x^2 - (\sum x)^2} \]

Offset is calculated using this formula:

\[ b = \frac{\sum y - \alpha \sum x}{n} \]

By using these formulas, we are able to calculate \( y \) for any given \( x \). In looking at the above figure, a number of items are immediately visible. The first, and most obvious are the two trend lines. We can clearly see that if the intervention had been allowed to continue that the AQ would continue to increase and the DQ would continue to decrease. In fact, using the phase 1 and phase 2, AQ and DQ calculated values and comparing the two, we see the participant’s AQ increasing from 00:27.871 (phase 1) to 01:01.166 (phase 2) and the DQ decreasing from 00:12.086 (phase 1) to 00:02.296 (phase 2). This means the participants attentiveness increased 00:33.295 seconds and the duration of a distraction decreased by 00:09.790 seconds, on average. This means the participant was able to remain focused for a little more than 33 seconds longer than he was able to at the start of the technological intervention and when distracted, his distractions were more than nine and a half seconds shorter in duration. This is significant because this change occurred in only 10 uses of the app over 16 calendar days, commencing when the app started delivering the intervention (phase 2).

Another item of interest is the separation between phase 1 values and phase 2 values and where we can see the app starting to deliver the intervention. Immediately following the fifth data point, the AQ values take a dramatic positive shift. The sixth data point, Nov. 27, was the beginning of phase 2 from the data file sent from this participant’s app, and we can clearly see immediate improvement starting on that date. The participant’s AQ on the last day of phase 1 was 00:13.559 and his AQ on the first day of phase 2 was 01:11.400; a difference of nearly a full minute (00:57.841). This is a very significant one-day change.
As the participant progressed through phase 2, we see fluctuations in the data points; some days the participant did extremely well, Dec. 1 – 02:37.932. Other days, not so well, Dec. 11 – 00:18.208. I can only attribute these fluctuations to the identified issues with the app. As previously mentioned, P1’s mother had contacted me via email during the technological intervention to indicate that some days the app would work, and others not. This could explain both the days with higher AQs and the days with lower AQs.

**Semi-Structured Interview Analysis**

Like the quantitative technological intervention, the semi-structured interview yielded some interesting results. In looking at the thematic analysis for this participant, the theme that appeared more than any other was that of focus. The first time the participant noted this was in response to being asked if he had noticed a change in attentiveness. He responded, “I felt like I was paying more attention.” He made other references to focus when asked if he had noticed any other positive changes in behaviour, stating, “In school, I found myself focusing more,” before I could even finish the question. The focus theme continued with additional responses such as, “it was easier to work; stay on task” and when asked if it was easier to block stuff out, he replied, “yes.” This was corroborated by his mother’s comment, “For the first week, it was really hard to motivate you [P] to do the half hour, but once the thing started buzzing, you became more into it when you were getting the buzzing feedback.” Indeed, P1’s scoring of attentiveness rated his change between five and six and his scoring of the intervention as a whole rated the overall experience as an eight. This is significant since it provides a partial response to my research question. Based on the information provided above, I can say that, for participant 1, one of the benefits of the technological intervention was increased focus.
Another theme that was evident in the responses from P1 was that of “blocking”, as was alluded to above. Blocking was coined to name the participant’s ability to “block” out distractions. Although the participant’s comment, “It was kind of like ‘oh, I already looked at that. I can look at that another time; let’s focus on this’,” may appear to be linked to the previous theme, focus, his comment is better attributed to being able to block out distractions. This comment was in response to being asked if he had noticed a change in distractibility and is equally significant as the focus theme for the same reason. Based on this, I can say that “blocking” is one of the additional benefits that the technological intervention provided.

Rewards were also an important theme for P1. This is evidenced by his mother’s comment, “without getting the immediate reward he wasn’t into it, but once it started buzzing, or doing whatever it was that it did, that really helped him.” Additionally, when asked about his favourite part of the intervention his response was, “I liked being able to level up.” Without the rewards there was no motivation for the participant to use the app. Based on these responses, I can answer the research question, what feedback can eye-tracking technologies provide students diagnosed with ADHD in order to improve their study behaviours? We can clearly see that the immediate feedback provided through the rewards system encouraged the participant’s attentiveness.

Combined Analysis

As mentioned in the results section, the app had some bugs that were not correctable in the time allotted; P1’s intervention was not immune. This was supported by his statement, “Yeah, like when I was looking directly at the iPad, it would buzz for no reason.” Knowing that the app was recording distractions when they didn’t exist meant that not only were the DQ calculations affected, because they were using more records than should have existed, so too
were the AQ calculations, because each time a distraction was recorded, the counter restarted, thereby reducing the time of attentiveness.

With this understanding, the comparison between phase 1 and phase 2, AQ and DQ does not reveal the true effectiveness of the intervention. Although the comparison looks very promising, its true value should have had a higher phase 2 AQ and lower phase 2 DQ, making the intervention even more effective than is reported.

The final two data points (Dec. 11 and 12) are also of interest. Here we see the participants AQ drop to levels similar to phase 1. This can be attributed to a number of areas. The first is the issues the participant was encountering. These on-again-off-again bugs would have certainly caused motivational problems for the participant, making him less willing to use the app. Additionally, and probably best stated by his mother, his schedule was getting increasingly busy. When discussing the participant’s motivation, she mentioned, “There were a few times near the end, and this became an issue for us, when our schedule really filled up and with band practice, soccer, school and travelling back and forth he simply couldn’t do it.” The increasingly busy schedule no doubt played an important part in P1’s attentiveness and as such could have affected his AQ for those days.

As mentioned above, there was a significant change in AQ as the participant moved from phase 1 to phase 2. We have also seen that the rewards played an important role in the participant’s motivation. Given that the participant’s increase in AQ occurred immediately after the app started delivering the intervention, I can only postulate, based on his mother’s comment, that once the app began providing immediate feedback (rewards) the participant’s motivation increased and he was more focused on the app, increasing his AQ score.
Case 2 – P2 (A-06)

P2 was a ten-year-old boy and was in grade five at the time of writing. He was formally diagnosed with ADHD one year prior to writing. During the time this participant was using the app, his mother contacted me to indicate some issues with the app; the app stopped levelling-up and the buzzing was near constant. They tried re-installing the app numerous times, but the same issues kept returning. He was taking medication but as discussed below, it was later found out that he was under-medicated for his body-weight. He had been using computing devices for five years at the time of writing.

Technological Intervention

In an effort to maintain clarity, the same column headers used in table 1 are used for table 2. For more information, please refer to the explanation in case 1 or appendix D. P2 completed three days of phase 1 and eight days of phase 2 of the technological intervention. He did not complete the entire intervention, citing changes in his schedule and Christmas holidays as reasons. His individual daily results are recorded in the following table:

Table 2

<table>
<thead>
<tr>
<th>Phase</th>
<th>Date</th>
<th>AQ</th>
<th>DQ</th>
<th>DTT</th>
<th># D</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>11/12</td>
<td>00:18.289</td>
<td>00:06.185</td>
<td>00:47:27</td>
<td>129</td>
</tr>
<tr>
<td>1</td>
<td>11/13</td>
<td>00:12.351</td>
<td>00:05.437</td>
<td>00:05:09</td>
<td>24</td>
</tr>
<tr>
<td>1</td>
<td>11/15</td>
<td>00:24.766</td>
<td>00:05.437</td>
<td>00:29:34</td>
<td>113</td>
</tr>
<tr>
<td>2</td>
<td>11/22</td>
<td>00:10.390</td>
<td>00:04.224</td>
<td>00:23:13</td>
<td>125</td>
</tr>
<tr>
<td>2</td>
<td>11/30</td>
<td>00:13.771</td>
<td>00:03.530</td>
<td>00:29:44</td>
<td>147</td>
</tr>
<tr>
<td>2</td>
<td>12/1</td>
<td>00:11.196</td>
<td>00:03.601</td>
<td>00:30:09</td>
<td>167</td>
</tr>
<tr>
<td>2</td>
<td>12/3</td>
<td>00:08.556</td>
<td>00:04.782</td>
<td>00:30:19</td>
<td>177</td>
</tr>
<tr>
<td>2</td>
<td>12/6</td>
<td>00:12.704</td>
<td>00:03.586</td>
<td>00:11:59</td>
<td>61</td>
</tr>
<tr>
<td>2</td>
<td>12/8</td>
<td>00:10.735</td>
<td>00:03.788</td>
<td>00:18:28</td>
<td>100</td>
</tr>
</tbody>
</table>
It is important to remind the reader that the calculated values above are derived from the entire raw data for that particular day. No records were removed and the data were not scrubbed in any way to ensure reliability, reproducibility, and transparency.

**Semi-Structured Interview**

As with case 1, the semi-structured interview was scheduled for a date following the technological intervention. The interviews included the participant (P), the parent(s) (mom (M) and dad (D), and myself, (ME). With the permission of all involved in the semi-structured interviews the sessions were audio recorded for easier transcription. In accordance with the information technology section the audio recordings were destroyed once transcription was completed. To gain a better understanding of the data in its entirety the un-edited transcript as well as my thoughts and observations recorded during the interview are provided in appendix G.

Immediately prior to the interview, the results from the technological intervention were discussed and explained. At this point, it is necessary to disclose that this participant is the older brother of P3. That said, the semi-structured interview was scheduled immediately following the interview of P3. The participant and myself sat across from each other with mom and dad sitting a bit farther away. Having verified the audio recording signals were adequate, no changes were necessary. The participant seemed eager to get started.

In follow-up to the semi-structured interview, I had a clarification question I sent to the participant’s mother in an email. During the interview for P3, P2’s brother, she commented on the need for a medication change. In my email I asked if P2 was also in need of a medication change.
Technological Intervention Analysis

As discussed in the results section, P2 completed three days of phase 1 and eight days of phase 2. Using the results recorded in table 2, P2’s results were plotted in a scatterplot-formatted chart and are provided next in figure 3.

Figure 5

![P2 (A-06) Phase 1 Combined Daily Results](image)

Figure 6
As with the tables, the chart components are repeated for ease of understanding and clarity with the X axis in dates with the Y axis being time duration in a minute:second.thousandths format (mm:ss.000). The data points are the AQ calculations, represented by diamond-style markers, and DQ calculations, represented by circle-style markers, for that specific date. The black connecting-line represents the connections between the AQ data points and the grey connecting-line represents the connections between the DQ data points. The dotted black line indicates the trend for the AQ if the intervention were to continue and the dotted grey line indicates the trend for the DQ if the intervention were to continue.

As we can see in this case, the AQ trend line is decreasing with the DQ trend line remaining fairly static with very minimal change (flat line). Given the problems this participant encountered during the intervention, I can only surmise the two are related however, since this
relationship crosses over both the quantitative and the qualitative results, this relationship will be discussed in more detail in the combined analysis section, below.

**Semi-Structured Interview Analysis**

Despite the issues P2 encountered while using the app, his parents’ view of its effectiveness did not seem affected. In response to the question of how they would rate the experience, they both rated it between a seven and an eight, with the parents commenting that they were “really happy” and “thought it was great.”

One very interesting bit of information that came out of the semi-structured interview results were the affects the app had on the participant when he was not using it. The participant’s father commented, “your behaviour is actually getting worse since you stopped using it. I think having the time right before bed that he needed to stay focused drained him somehow and took away from the excess he had before and made it easier to get him to bed.” Asking him to clarify, he stated, “Recently, it’s been hard getting him off to bed. Since he’s not been using the app, he’s not draining that pool and has extra energy. He’s just hyper and crazy. Maybe since he’s not focusing on the app anymore, he has nowhere to use up that energy.” These comments indicate the effect that the app had on the participant during use, and once the intervention had ceased, he returned to the way he had been pre-intervention. Although the app uses operant conditioning theory to deliver both the positive reinforcement (reward) and the positive punishment (buzzing) the above described effect cannot be attributed to extinction. Extinction occurs when a reinforced behaviour is no longer reinforced by providing stimulus (reward/punishment) and returns to its previous state. Since the app was not being used to prepare the participant for bed, there was no reward nor any punishment for good or bad behaviour related to same and therefore extinction cannot occur. I can only conclude that this
behaviour, like his father commented, was a result of being keenly focused immediately prior to his evening rituals, draining some of his energy and making him more focused on preparing himself for bed.

Another interesting comment made in the semi-structured interview was made by the participant’s mother. She commented, “If I was using this normally, to help him, I would be using it in the middle of the day when his meds could help him to learn to be more attentive. I think this [app] in conjunction with the meds would be amazing!” This provides some interesting insight since it is widely accepted that combined treatment methods, both pharmacological and behavioural, are far superior to one or the other alone. This ideology is confirmed in an article by Peter Jensen, MD et al. for The Multimodal Treatment Study of Children with Attention-Deficit/Hyperactivity Disorder Cooperative Group, where he writes, “in several instances, combined treatment proved superior to intensive behavioral treatment,” (1999, p. 1073). This means that although the app was effective in increasing attentiveness and reducing distractibility, those effects would have been more pronounced had the participant been using the app during the daytime when his medication was fully performing. If you recall, the participants were instructed to use the app during the evenings, as late as possible, to reduce any effects the medication might have had and to provide a clearer picture of the effectiveness of the technological intervention.

**Combined Analysis**

As mentioned in the technological intervention section, this participant (P2) had numerous problems with the app. It would inexplicably stop allowing the participant to level up, and would start delivering the punishment (buzzing) portion of the intervention without reason and when the participant was looking directly at the device. This is evidenced by a number of
emails between myself and his mother where she had tried reinstalling the app numerous times only for the issues to return. Without being able to level up, the participant’s motivation to use the app and to better his attentiveness would have undoubtedly been affected. This is reinforced by the participant’s comment, “I really noticed that once I started to level up that I was more focused,” indicating that he was less focused when the app wasn’t delivering the intervention. Without the reward portion of the intervention, and by his own comments, his focus was reduced, thereby affecting his AQ and quite possibly his DQ.

In trying to determine a reason why this participant’s AQ would drop over the course of the intervention, and having found no reasonable reason in the quantitative data, I looked back into the semi-structured interview. It was here that I found a comment by the participant’s father; “there haven’t been recent changes in his medication and we’re noticing changes in his behaviour outside the app. He’s currently under-medicated based on his body-weight, so at the end of the day, there’s changes that we’ve noticed, that might influence any positive changes that would come from the app.” This comment was found in the transcript for, and references P3. In a clarification email sent to both participant’s mother, since both participants are brothers, she clarified that in addition to P3, P2 was not only under-medicated for his body-weight, he appeared to be more in need of a medication change than his sibling. Although I envisioned the intervention to be done with the least effects of medication possible, it is undoubted that some of those effects were still present in the participants during their use of the device. Given that P2 would have been experiencing less of those effects because of his under-medicated state when taking the intervention, and because of the issues with the app, his AQ would have certainly been affected.

Case 3 – P3 (A-07)
P3 was an eight-year-old boy and was in grade three at the time of writing. He was previously formally diagnosed with ADHD two years prior to writing. He was taking medication, but like his brother, above, it was later found out that he was under-medicated for his body-weight. He had been using computing devices for three years at the time of writing.

**Technological Intervention**

To maintain simplicity, the same column headers used in the previous tables are used for table 3. For more information, please refer to the explanation in case 1 or appendix D. P3 completed three days of phase 1 and eight days of phase 2 of the technological intervention. He did not complete the entire intervention, citing changes in his schedule and Christmas holidays as reasons. His individual daily results are recorded in the following table:

<table>
<thead>
<tr>
<th>Phase</th>
<th>Date</th>
<th>AQ</th>
<th>DQ</th>
<th>DTT</th>
<th># D</th>
</tr>
</thead>
<tbody>
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<td>00:04.622</td>
<td>00:33:44</td>
<td>159</td>
</tr>
<tr>
<td>1</td>
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<td>00:10.176</td>
<td>00:10.149</td>
<td>00:28:51</td>
<td>102</td>
</tr>
<tr>
<td>1</td>
<td>11/19</td>
<td>00:12.665</td>
<td>00:02.512</td>
<td>00:05:14</td>
<td>29</td>
</tr>
<tr>
<td>2</td>
<td>11/21</td>
<td>00:15.166</td>
<td>00:10.119</td>
<td>00:14:42</td>
<td>48</td>
</tr>
<tr>
<td>2</td>
<td>11/22</td>
<td>00:10.623</td>
<td>00:08.837</td>
<td>00:40:07</td>
<td>68</td>
</tr>
<tr>
<td>2</td>
<td>11/30</td>
<td>00:24.174</td>
<td>00:06.100</td>
<td>00:36:32</td>
<td>146</td>
</tr>
<tr>
<td>2</td>
<td>12/1</td>
<td>00:10.149</td>
<td>00:05.549</td>
<td>00:18:32</td>
<td>90</td>
</tr>
<tr>
<td>2</td>
<td>12/3</td>
<td>00:13.596</td>
<td>00:04.615</td>
<td>00:26:32</td>
<td>136</td>
</tr>
<tr>
<td>2</td>
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<td>00:05.492</td>
<td>00:16:07</td>
<td>67</td>
</tr>
<tr>
<td>2</td>
<td>12/8</td>
<td>00:09.521</td>
<td>00:07.042</td>
<td>00:27:46</td>
<td>129</td>
</tr>
<tr>
<td>2</td>
<td>12/9</td>
<td>00:13.689</td>
<td>00:02.785</td>
<td>00:09:33</td>
<td>123</td>
</tr>
</tbody>
</table>

As with the previous cases, no records were removed and the data were not scrubbed in any way to ensure reliability, reproducibility, and transparency.

**Semi-Structured Interview**
The semi-structured interview was scheduled at a date following the termination of phase 3 of the app. The interviews included the participant (P), the parent(s) (mom (M) and dad (D), and myself, (ME). With the permission of all involved in the semi-structured interviews the sessions were audio recorded for ease of transcription. In accordance with the information technology section the audio recordings were destroyed once transcription was completed. To gain a better understanding of the data in its entirety the un-edited transcript as well as my thoughts and observations recorded during the interview are provided in appendix H.

Immediately prior to the interview, the results from the technological intervention were discussed and explained. Being the second interview in the same environment, the seating arrangement remained constant with the participant and myself sitting across from each other with mom and dad sitting a bit farther away and I was concerned that the audio recording would not capture their voices should they have any responses to provide. Volume levels were checked and corrected. The participant seemed eager to get started but visibly had impulse control issues resulting in apparent inattentiveness.

**Technological Intervention Analysis**

As discussed in the results section, P3 completed three days of phase 1 and eight days of phase 2. Using the results recorded in table 3, P3’s results were plotted in a scatterplot-formatted chart and is provided next in figure 4.

Figure 7
Figure 8

P3 (A-07) Phase 1 Combined Daily Results

P3 (A-07) Phase 2 Combined Daily Results
As with the tables, the chart components are repeated for ease of understanding and clarity. For a description of chart components please refer to case 1 or appendix E.

In this chart, we see the trend line for AQ increasing and the trend line for DQ decreasing, albeit minimally. From the chart, we can see that if the intervention had been allowed to continue that the AQ would continue to increase and the DQ would continue to decrease. Using the phase 1 and phase 2, AQ and DQ calculated values and comparing the two, we see the participant’s AQ increasing from 00:11.903 (phase 1) to 00:15.151 (phase 2) and the DQ decreasing from 00:06.355 (phase 1) to 00:05.887 (phase 2). This means the participants attentiveness increased 00:03.248 seconds and the duration of a distraction decreased by 00:00.468 seconds, on average. This means the participant was able to remain focused for a little more than 3 seconds longer than they were able to at the start of the technological intervention and when distracted, his distractions were slightly less than half of a second shorter in duration. Although these results are not as significant as case 1, they still show promise because these changes occurred in only eight uses of the app over 19 calendar days.

As previously discussed in the qualitative analysis for P2, and since both boys are brothers, there may have been unaccounted-for, external influences affecting the efficacy of the intervention. As in the previous case, and since the answers lie in the qualitative results, they will be discussed in the combined analysis, immediately following the semi-structured interview thematic analysis, next.

Semi-Structured Interview Analysis

A common theme throughout the results, and not P3 specifically, were the issues with the app. Since these issues are discussed in more detail in the thematic analysis section, below, they
will not be discussed here. Overall the participants scored the effectiveness of the intervention as a 7, with the participant’s mother commenting, “I was really impressed with how he [P] responded.”

One of the more common themes that presented itself from P3s results was that of determination. When asked the question of whether or not they noticed any positive changes in behaviour, the participant’s father responded, “I definitely noticed he had more determination once he got used to it.” The participant’s mother added to this comment, “Maybe those positive reinforcements kind of helped him to be less irritated by the small things and endure the irritation a little better and be more patient; that determination. I didn’t really expect that of him. He got a lot farther in the program [intervention] that I would have thought he would. I thought he would have ‘checked-out’ earlier, but he stuck in.” These comments indicate that once the app started delivering the intervention, and subsequently started producing false-positives, the participant was more determined to endure the problems and continue with the intervention. Based on this, I can say that “determination” is one of the additional benefits that the technological intervention provided.

Another theme that was prevalent in case 3 was that of rewards. As referenced in the previous paragraph, even the participant’s mother was surprised that he continued the intervention as long as he did. When asked if there was a change in attentiveness, she replied, “oh, for sure… I definitely noticed as it went on that he was more attentive. For [P] in particular, I thought it would be impossible for him to focus longer, but it was good motivation.” This comment reveals a couple of items for discussion. The first is a connection between the quantitative and qualitative results and as such will be discussed below in the combined analysis section. The second is the importance of the rewards in building intrinsic motivation. Albeit a
simple reward structure, that of levelling-up, it was still enough to encourage the participant to continue using the app even though there were known issues. This would indicate, and in response to the research question, one piece of feedback that eye-tracking technologies can provide students diagnosed with ADHD in order to improve their study behaviours is rewards. Giving the participant a reward for desired behaviour, in this case levelling-up in response to attentiveness, reinforces the desired behaviour by making the participant feel good about himself, which in turn builds intrinsic motivation to be more attentive to receive the next reward.

Building from the rewards theme, and since they are closely related, the final theme in P3’s results to be discussed is that of blocking. As previously mentioned in the first case analysis, blocking was coined to name the participant’s ability to “block” out distractions. On numerous occasions, P3 exhibited this behaviour leading his mother to comment, “I thought he did a lot better at blocking out the distractions,” when questioned about noticing a change in distractibility. This shows that regardless of the known issues with the app, the participant was still able to block out distraction and remain attentive to the app. This leads me to question the minimal improvements in the quantitative results, but given that this discussion crosses both the quantitative and qualitative results, it will be discussed next, in the combined analysis.

Combined Analysis

As discussed in the second case study, under-medication could have played an important role in the participant’s attentiveness and distractibility thereby affecting the results and the AQ and DQ calculations. Although the quantitative results indicate only marginal improvements, the semi-structured interview revealed a perceived success with the intervention, pitting the two methodologies against each other in a contradictory battle. With prior knowledge of the issues
with the app, the false-positives being generated, I am more convinced by the responses in the interview than I am with the calculations from the intervention.

As with the other cases, bugs in the app were an ongoing issue and P3 was no exception. It has been shown above that P3 endured those issues and still managed to block out distractions. Then why do his quantitative results only show minimal improvement? I can only postulate that, similar to P2, the false-positives being created in the app affected the AQ and DQ calculations, making it appear that the intervention was less effective than it actually was.

**Case 4 – P4 (A-11)**

P4 was a thirteen-year-old boy and was in grade eight at the time of writing. He was formally diagnosed with ADHD six years prior to writing. He was taking medication and had been using computing devices for eleven years at the time of writing.

**Technological Intervention**

To maintain simplicity, the same column headers used in the previous tables are used for table 4. For more information, please refer to the explanation in case 1 or appendix D. P4 completed four days of phase 1 and eight days of phase 2 of the technological intervention. He did not complete the entire intervention, citing issues with the app and Christmas holidays as reasons. His individual daily results are recorded in table 4:

Table 4

<table>
<thead>
<tr>
<th>Phase</th>
<th>Date</th>
<th>AQ</th>
<th>DQ</th>
<th>DTT</th>
<th># D</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>11/9</td>
<td>00:15.264</td>
<td>00:05.049</td>
<td>00:31:19</td>
<td>126</td>
</tr>
<tr>
<td>1</td>
<td>11/11</td>
<td>00:42.485</td>
<td>00:03.784</td>
<td>00:58:08</td>
<td>153</td>
</tr>
</tbody>
</table>
As with the previous cases, no records were removed and the data were not scrubbed in any way to ensure reliability, reproducibility, and transparency.

**Semi-Structured Interview**

The semi-structured interview took place at a date following the participant’s completion of the technological intervention. The interviews included the participant (P), the parent (dad (D)), and myself, (ME). With the permission of all involved in the semi-structured interviews the sessions were audio recorded for easier transcription. In accordance with the information technology section the audio recordings were destroyed once transcription was completed. To gain a better understanding of the data in its entirety the un-edited transcript as well as my thoughts and observations recorded during the interview are provided in appendix I.

Immediately prior to the interview, the results from the technological intervention were discussed and explained. The participant, his father, and myself sat across from each other at a round table providing equal access to the audio recording device.

**Technological Intervention Analysis**

As reported, P4 completed four days of phase 1 and eight days of phase 2. The results recorded in table 4 were plotted in a scatterplot-formatted chart, shown in Figure 5:
Figure 9

P4 (A-11) Phase 1 Combined Daily Results

Figure 10

P4 (A-11) Phase 2 Combined Daily Results
As with the tables, the chart components are repeated for ease of understanding and clarity. For a description of chart components please refer to case 1 or appendix E.

In looking at the above figure, a number of items are immediately visible. The first, and most obvious are the two trend lines. We can clearly see that if the intervention had been allowed to continue that the AQ would continue to increase and the DQ would continue to decrease. Although the trend line appears to show improvement, using the phase 1 and phase 2, AQ and DQ calculated values and comparing the two, we see the participant’s AQ increasing from 00:29.986 (phase 1) to 00:30.161 (phase 2) and the DQ decreasing from 00:04.438 (phase 1) to 00:04.434 (phase 2). This means the participants attentiveness increased 00:00.175 seconds and the duration of a distraction decreased by 00:00.004 seconds, on average. These results on their own are not very significant but when analyzed in combination with the results from the semi-structured interview are explainable. This will be discussed in more detail in the combined analysis section for this case study, below.

Another item of interest is the separation between phase 1 values and phase 2 values and where we can see the app starting to deliver the intervention. Immediately following the fourth data point, the AQ values take a dramatic positive shift. The fifth data point, Nov. 16, was the beginning of phase 2 from the data file sent from this participant’s app, and we can clearly see immediate improvement starting on that date. The participant’s AQ on the last day of phase 1 was 00:10.316 and his AQ on the first day of phase 2 was 00:32.508; a difference of more than 22 seconds (00:22.192). This is a very significant one-day change.

Semi-Structured Interview Analysis
Even though P4 encountered many issues while using the app, his perception of its effectiveness did not seem affected. In response to the question of how he would rate the overall experience, he rated it an eight. This that means although he had difficulties with the app, he still felt the app provided value. In this context, value is considered to be the relationship between the positive changes and the bugs and here we see the participant rating the overall experience high even with the issues encountered.

When analyzing this case for themes, one presented itself more than others; focus. More than once the participant commented on changes in concentration. For example, when asked if he had noticed a change in attentiveness, he responded, “I did notice a difference in class. I was able to concentrate more in class.” To clarify, I questioned how he felt he was able to concentrate more in class and he supplied, “Like, if there was something going on in the hall, I’d tell myself to ignore it and stay focused. A lot of the times, I was able to do it.” These comments suggest that this participant was able to take the principles of the app and apply them to an external environment. Indeed, and by his own admission, “I felt like I was able to concentrate more; I could stay focused more on what I had to do at school.” This is significant because this change occurred after only eight days of the app delivering the intervention and 12 days in total. This would indicate, and is supported by the other case studies, that one of the major benefits of using this technological intervention is focus. In this case, it was not the focus the participant had towards the app, but more so the transferability of this focus to an external environment namely, his school.

Another prevalent theme in this case was blocking. As you recall, blocking was coined to provide a name to the participant’s ability to block out distractions. This participant expressed this ability when questioned if he had noticed a change in distractibility. His comment, “I did
notice a difference. I was able to block distractions out a bit better. I would start to feel
distracted by something and tell myself, I don’t want to look at it; I want to keep looking at the
iPad,” shows his intrinsic motivation to stay focused by blocking out distractions that might have
otherwise taken him off-task. Even this participant’s father commented on this, “I think he did
amazingly well to block everything out, or at least as much as he did.” This demonstrates that
not only did the participant notice a change, but so did his father, indicating that blocking is an
additional benefit this technological intervention provided.

One comment in particular was made by this participant. When asked to rate the overall
experience he replied, “I felt different when I was using it and that made me feel better. I felt
like I could concentrate more.” This would indicate the participant had a small increase in self-
esteeem because knowing he was getting better at concentrating, he felt like he could concentrate
more slightly improving his self-view. Lower self-esteem is a common issue for people with
ADHD (Slomkowski et al., 1955) and anything that can help them improve on how they feel
about themselves can only be a benefit.

**Combined Analysis**

As the participant progressed through phase 2, we see fluctuations in the data points;
some days the participant did extremely well, Nov. 19 – 00:50.522. Other days, he did not so
well, Nov. 13 – 00:10.316. I can only attribute these fluctuations to the identified issues with the
app. As previously mentioned, the topic of bugs was prevalent prior to and in the semi-
structured interview indicating that some days the app would work, and others not. This could
explain both the days with higher AQs and the days with lower AQs.
With this understanding, the comparison between phase 1 and phase 2, AQ and DQ does not reveal the true effectiveness of the intervention. In this case, we see very little change between phase 1 and phase 2, but its true value should have had a higher phase 2 AQ and lower phase 2 DQ, making the intervention even more effective than is reported.

As mentioned above, there was a marginal change in AQ as the participant moved from phase 1 to phase 2 (+00:22.192). We have also seen that the rewards played an important role in the participant’s motivation. Given that the participant’s AQ increase occurred immediately after the app started delivering the intervention, I can only postulate that, once the app began providing immediate feedback (buzzing) the participant’s motivation increased and he was more focused on the app, increasing his AQ score. His comment, “I really liked the buzzing. For the first week I was like, what does this thing do, but then it kicked in and was really cool!” directly contributes to this analysis.

**Thematic Analysis**

Once the individual cases had been thoroughly examined, the results from the qualitative, semi-structured interviews were coded and analyzed to see if there were any recurring themes that were present across all of the participant responses. What I found was that there were in fact commonalities in how the participants responded to the different questions. Those commonalities were the bugs, focus, and blocking and are described below.

**Bugs**

One of the more common themes found throughout the participants’ responses revolves around the issues in the app namely, the bugs. These bugs are errors in coding, or programmatic errors, producing incorrect, un-anticipated results. Two different types of bugs presented
themselves; the buzzing and the disappearance of the levelling-up. Unfortunately, given the time constraints of the technological intervention, there was no possible way the app could be corrected in time for any update to be of use. The bugs were responsible for false-positives, where the app would buzz the participant when he was looking directly at it. P4 explained it best when he stated, “The bugs! I’d be like, looking straight at the iPad and it would buzz me. I couldn’t be paying more attention to it!” Apart from the bugs, none of the participants complained of any other negative effects, which is telling in itself.

The bugs themselves presented difficulties in interpreting the quantitative data since there were both direct and indirect effects the bugs had. The direct effect these bugs had in using the raw data and interpreting the results is the effects the bugs directly had on the AQ and DQ calculations. AQ and DQ are calculated values and since the app was recording false-positives, those same false-positives are erroneously included in those calculations. Since it was unknown which records were false-positives, the data could not be cleaned to remove errors, and consequently, all data shown in this paper are based on the raw data.

Another effect the bugs had on the participants was motivation, but this was more indirect. We have already seen that even though the reward system built into the app was a simple, levelling-up, it was satisfactory enough to motivate the participants to try harder and to maintain focus by blocking out the distractions. When the levelling-up disappeared, it would have had a definite effect on that participant’s motivation to continue using the app. This lowered motivation would have presented itself in the form of more and longer distractions and less attention, again affecting the AQ and DQ calculations.

**Blocking**
Unlike the previous theme, this one had better outcomes. The blocking theme was found in all four participants’ comments and in some cases, was mentioned numerous times. In all of the cases, the participants were responding to the question of whether or not they had noticed a change in distractibility. As described individually in the cases, all participants responded that they had noticed change and resoundingly stated that they all benefited from being able to block out distractions and focus on the task at hand. These are very promising results given the relatively short period of time that the technological intervention was able to perform its function. In looking at all of the results from all participants, I can definitely say that one of the more important additional benefits using a technological intervention such as this one is blocking.

Focus

The theme that was found most often in the qualitative results was that of focus. This is evidenced by discussions in the individual case studies. Overall, it was repeated across all four participants’ transcripts and was found in response to numerous questions. Unequivocally, all four participants stated their focus had increased from the time they started the intervention to the time they stopped. Again, these are very promising results given the time allotted to perform the research. In returning to my research questions, I can say that the most important benefit this technological intervention provided was focus.

Overall Effectiveness

As a final review, I wanted to look at the overall effectiveness this intervention had on the participants. Since understanding the intervention from a holistic perspective required viewing the data as a whole, and not split between quantitative and qualitative, it could not be
discussed until now. In review of the overall effectiveness, I will look at a number of different areas including medication, positive change, and ratings.

**Medication**

As shown in the individual case studies, specifically for the two brothers, P2 and P3, medication, or in these cases the lack thereof, played an important role in the overall effectiveness of the intervention. In contrast to P1 and P4, who were not taking medication or whose medication was at a proper dosing level, their quantitative results did not appear as promising as P1 and P4. Again, in contrast, the results from the qualitative data seemingly contradict the quantitative results for these participants showing effectiveness where it wasn’t necessarily clear from the quantitative results only. One thing for future researchers to consider will be to use this technological intervention simultaneously with medication. Indeed, and as one of the parents commented, “I think this [app] in conjunction with the meds would be amazing!”

**Positive Change**

The positive change theme was the most common theme from all of the responses from all of the participants. This theme appeared in more than 15 different responses from the semi-structured interview transcripts and from the technological intervention, quantitative results. When looking at the quantitative data from the technological interventions, three out of the four participants had positive changes in both their attentiveness, measured by AQ, and their distractibility, measured by DQ. When asked if the participant had noticed a change in attentiveness, the participants unanimously responded, yes. When asked if they had noticed a change in distractibility, the participants unanimously answered, yes. And finally, when asked if they had notices any other positive change in behaviour, again, the reply was again, unanimously, yes. These results are extremely encouraging. Granted, only four participants
were able to complete enough of the technological intervention to be included in these results, but the fact that 100% of them found there was positive change in their daily lives, with and without the intervention, is very promising.

**Ratings**

The review of the overall effectiveness of the intervention would not be complete without reviewing the overall ratings, or the scores the participants attributed to different aspects of the intervention. These ratings are only numeric in value, but what they provide in corroboration is without measure.

When asked to rate the change in attentiveness, on a scale of one to ten, where one is no change and ten is an extreme change, the participants rated it as 5.5, on average (P1=6, P2=5, P3=4, and P4=6). When asked to use the same scale of one to ten to rate the change in distractibility, the participants rated it as 6.5, on average (P1=7, P2=6, P3=6, and P4=7). Finally, when asked to rate the overall effectiveness of the intervention, on the same one to ten scale, the participants rated it as 7.75, on average (P=8, P2=8, P3=7, and P4=8). These ratings are very telling of how the participants perceived the overall experience. It appears that regardless of the issues encountered during the use of the intervention, they all perceived the intervention as being very effective. Indeed, the participants own verbal testimonies reaffirm these findings.

**Chapter 5 – Conclusions and Recommendations**

In order to form any conclusions on the efficacy of the technological intervention, we must first review the research questions: What benefits can an eye-tracking technological-intervention designed to increase attentiveness and reduce distractibility provide elementary
school children ages six through thirteen diagnosed with ADHD? Additionally, this research specifically tried to answer:

1. What feedback can eye-tracking technologies provide students diagnosed with ADHD in order to improve their study behaviours?

2. What additional benefits can be realized using this technological intervention?

As we have seen in the analysis section, there are many benefits this technological intervention provided. By far, the most beneficial as stated by the participants, was focus. Not only were they motivated by the app to focus during app usage, in some cases they were able to transfer this skill to outside environments, such as their schools.

Another benefit coming directly from the technological intervention was the concept of blocking. As you recall, blocking refers to the participants’ ability to block out distractions, staying on-task. This benefit was unanimously repeated by all of the participants, indicating that it was something they had all taken note of in the past and noticed a significant personal change by the end of the intervention. As with the focus benefit, we saw blocking being transferred to an external environment, again school. This is again worthy of making note that this benefit was realized in a relatively short time-frame; P1 used the intervention the most at 15 times in 26 calendar days.

The feedback provided by the app was an integral component to the technological intervention, as was previously thought. Indeed, as discussed in chapter 2 – the literature review, OC has been an effective tool in behavioral interventions/therapies and my research only reaffirms its effectiveness. The participants agreed that although annoying, the buzzing was the most effective way to retake their attention from a distraction, even if it was to just, “shut it up.”
Still effective, but to a lesser extent, the levelling-up provided an adequate reward system. In the semi-structured interviews, it was disclosed that perhaps changing the levelling-up to a game may increase motivation. This will need to be considered for future iterations of this research. By incorporating OC directly into the app, it becomes portable allowing the student to use it anywhere. It also allows the student to use the intervention autonomously and without help.

As mentioned in chapter 2, reading comprehension is a challenge for students with ADHD. This is due in part to their lack of sustained attention (Tsal et al., 2005, Stern & Shalev, 2013). As shown above, after using the technological intervention, all participants indicated a positive change in their sustained attention; they were able to remain focused longer. Knowing that sustained attention is a key factor in students’ reading comprehension and knowing that the technological intervention increased the students’ sustained attention, I can postulate that this intervention could help students increase their reading comprehension abilities, but more research needs to be done.

Learning theories, as considered in the literature review, were important components in this research. Operant conditioning, as mentioned above played a vital role in the positive modifications of the students’ behaviours. By modifying the reward structure, as suggested by the participants, I am certain this intervention could be made to be more effective.

Another connection to the literature review is the fact my app used BITs to modify behaviour. This was done by designing the app to integrate into the students’ daily lives specifically, their homework. As stated in chapter 2 the deeper the integration of the intervention, the better overall effect it will have. Understanding the significant positive results as shown by all participants in only thirty minutes of use each evening leads me to surmise that
the effects of this intervention would be increased if the app was further integrated into their
daily lives namely, school. If this level of integration is achieved, I am certain that the positive
effects the participants felt would be amplified, ever increasing their self-esteem.

At the outset of this research it was unknown if the front-facing cameras in most smart-
devices had enough resolution to detect and track the students’ eyes. In previous research, as
discussed in the literature review, it had been proven that these front-facing cameras had enough
accuracy to track the eyes of sleepy drivers, but it was unsure if the same could be said for track
the eye-movements, as a whole. Given the results shown by the participants, I can conclude that
these front-facing cameras are of enough resolution to track students’ eye-movements to track
and record their attention and distraction.

Overall, I can conclude that this research was successful in answering the research
questions. The technological intervention was able to modify the participants’ behaviours
making them more attentive and less distracted. It provided and exposed many immediate and
longer-term benefits and it showed that the feedback structure of the rewards and punishments
was adequate to effect change. More research is definitely needed, but the results from this
intervention raise hope for children and parents alike that there will soon be additional tools to
help children to be more attentive, less distracted, and generally feel better about themselves
while learning how to deal with their disorder.

There are a number of future directions this research should take, both short-term and
long-term. First and foremost, more research needs to be done. There are many very promising
opportunities my research exposes, but more needs to be known. One very immediate direction
this research should take is to correct the errors, establish a larger group of participants, and
follow those participants for a longer period of time. Perhaps an option to this would be to have
the participants use the device twice in a day; once when their medication is in full-effect, and
once later in the evening, when the medication has less of an effect on the participants’ impulse
control.

As mentioned early in this paper, there is only one definitive biological test that can
detect ADHD; the EEG. Unfortunately, this technology can be quite scarce, installed in only a
few hospitals throughout Canada. Using this eye-tracking technological intervention opens new
doors that were not previously open. Perhaps if enough participants can be gathered, both with
and without ADHD, a comparison can be made between those with ADHD and the so-called,
normal-functioning persons, allowing researchers to define AQ and DQ ranges for both groups.
This may lead to a low-cost, reliable, and portable biological test for ADHD. The implications
of this are great since the number of children being diagnosed with ADHD is increasing annually
(CDC, 2012). Some consider this increase as a result of over-diagnosis attributed to under-
educated medical professionals, for example rural general-practitioners. With further research,
this proof of concept could help said professionals more accurately diagnose this disorder.

As front-facing cameras are released with greater resolutions, their accuracy increases.
Perhaps there will be a time in the not-too-distant future where we are able to track the individual
eye-movements (saccades, SPEM, vergence, and vestibulo-ocular movements). If this becomes
reality, applying my research to those affected with dyslexia could offer hand-held solutions to
aid in learning. For example, knowing the specific eye-movements that indicate when a dyslexic
person is having trouble recognizing a character or word and knowing which character or word
was at issue, the app could adaptively change the offending character or word to one using a
dyslexic-friendly font thereby making it easier to read.
One interesting direction this technology could offer is not related to ADHD specifically. For years marketing companies have researched where consumers look in different advertisements. This research usually involves the participants wearing bulky head-wear with cameras mounted towards the eyes that track where the participant is looking. Given the requirements of using this technology, for example, cost of technology, cost of centralized location to conduct research, cost of participant’s inconvenience (travel, specific times), the ability to conduct this type of research can be impeded. Using derived technology from my proof of concept, this type of research could be available to more companies.

Although I’m sure there are many, one final avenue my research could be applied to would be that of Human Interface Devices (HID). Imagine someone who has lost the ability to control his or her body from the neck down, for example quadriplegics or victims of stroke. By tracking where their eyes are on the screen, and how their eyes interact with the items on the screen, perhaps new ways of controlling computers can be developed.
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doi:10.1177/0731948712438556
Appendix A – Call for Volunteers

Dear parent,

My name is Ric Sack, and I am a graduate student at Royal Roads University in the MA Learning and Technology program. I am doing research which might help your child learn to control their focus and attention. In my research, I will talk with many children, parents and teachers and ask them a number of questions. Whenever researchers study children, we talk to the parents and ask them for their permission to take part.

You are receiving this invitation because your child has been diagnosed with ADHD and is within the age group that have not yet begun to develop their own ADHD-specific coping skills.

Previous studies have shown that attention-span is something that students can learn. My research is intended to look deeper at how technology can help students in this effort.

There are two types of research that will be done. The first one is using an app on a tablet that tracks the child’s eye movements. The second will be done by interviewing you, your child, and your child’s teacher (if permitted) to capture additional information that may not have been found using the app.

You do not have to make a decision today. Before you make any decisions, I encourage you to discuss the research with anyone you feel comfortable with. Additionally, you or your child may decide to stop participating at any time, and this decision will not affect your, nor your child’s future in any way.

If you have any questions, you may ask them at any time, even after the research has started. I can be contacted at or on my cell phone at.
If this might be of interest, I encourage you to complete the survey questions, on page 3, and contact me using either method above. I will explain the research in more detail and provide you with an unlimited number of opportunities to ask questions allowing you to make a free and informed decision.

Thank you for your consideration and interest!

Ric Sack
Pre-Technological Intervention Survey

1. How many years has your child been using computers/tablets/smartphones? (1-13)
   Click here to enter text.

2. Has your child been formally diagnosed with Attention Deficit Disorder (ADD) or Attention Deficit Hyperactivity Disorder (ADHD) by a health care professional? (Yes/No)
   Click here to enter text.
   a. If yes;
      i. How many years has it been since your child was diagnosed with this disorder? (<1, 1-2, 3-5, >5)
         Click here to enter text.
      ii. Is your child currently taking medication to treat this disorder? (Yes/No)
         Click here to enter text.

3. What grade is your child currently in? (open-ended)
   Click here to enter text.

4. How old is your child? (open-ended)
   Click here to enter text.

5. What is your child’s gender? (open-ended)
   Click here to enter text.

6. Do you own an android device? (Yes/No)
   Click here to enter text.
Appendix B – Free and Informed Consent

Free and Informed Consent Form for _______________________

This free and informed consent form is for parents of elementary school children aged 6-13, diagnosed with Attention Deficit Disorder, and participating in the research titled, “On Task: Increasing Attentiveness in Students with Attention Deficit Disorder.”

Ric Sack-Principal Researcher, graduate student Royal Roads University

This Free and Informed Consent Form has two parts:

- Information Sheet (to share information about the study with you)
- Certificate of Consent (for signatures if you agree that your child may participate)

You will be given a copy of the full Informed Consent Form

Part I: Information Sheet

Introduction

My name is Ric Sack, and I am a graduate student at Royal Roads University in the MA Learning and Technology program. I am doing research which might help your child learn to control their focus and attention. In my research, I will talk with many children, parents and teachers and ask them a number of questions. Whenever researchers study children, we talk to the parents and ask them for their permission to take part. After you learn a bit more about the study, and if you agree, I will then ask your child if they would like to take part. You both have to agree independently before I can begin.

You do not have to make a decision today. Before you make any decisions, I encourage you to discuss the research with anyone you feel comfortable with.

If at any time, you do not understand something, be it a word or terminology, please do not hesitate to question me. I will be more than happy to take whatever time is necessary to explain it and help you understand.

Purpose

Previous studies have shown that attention-span is something that students can learn. This research is intended to look deeper at how technology can help students in this effort.
Type of Research Intervention

There are two types of research that will be done. The first one is using an app on a tablet that tracks the child’s eye movements. This will be explained more in the Procedures section, below. The second will be done by interviewing you, your child, and your child’s teacher (if permitted) to capture additional information that may not have been found using the app.

Selection of Participants

You are receiving this invitation because your child has been diagnosed with ADD and is within the age group that have not yet begun to develop their own ADD-specific coping skills.

Voluntary Participation

I completely understand that any decision that potentially affects the welfare of your child can be difficult, and you do not have to agree to take part in this research. Since I will not know who you are unless you contact me, there is no way a decision to not take part can negatively affect you. You are free to ask as many questions as you need to feel comfortable about the whole process. As mentioned previously, you do not have to decide today, and I encourage you to take your time before deciding.

Procedure

The research will have two parts: The app and the interviews.

The app will learn the eye movements of your child and over time determine how easily distracted s/he is. Once it knows this, and if your child is distracted, it will start to shake the on-screen image trying to grab your child’s attention. If it does not, the app will shake the whole tablet to remind them to come back. Over the next little while, the time between the distraction and the shaking is decreased. At the end of this period, the app re-learns how easily distracted your child is. I then compare the first numbers to the last to see if there is a change.

The interviews will be done in your home or a mutually agreed on meeting place at a time of your convenience. The participants for the interview will be you and your child, unless your child asks for another person to be there. If you or your child does not want, for any reason, to answer any of the questions during the interview, they may simply say so, and I will move on to the next question. The interviews will be recorded for integrity and transcription purposes. The information recorded is confidential and no one other than me will have access to it. You do have the right to request the interview not be recorded. If this is your choice, I will look at alternate methods to collect the interview question responses. The recordings will be destroyed immediately once transcription is complete. To further protect your confidentiality, your and your child’s responses will be assigned a code, and no identifiable information will be kept.

Duration
I am asking that your child participate a half hour each evening, Monday to Friday over a three-month period, for a total of 30 hours with an additional half hour for the interview.

**Benefits**

There are a number of benefits that could be realized. If the intervention works, your child’s attention span will increase and their ability to control or block out distractions will improve. This new attention span will undoubtedly have effects in other aspects of their lives; sibling interactions, homework, self-esteem. Beyond the immediate family benefits, there should also be changes in their attention in class. This will be explored by interviewing your child’s teacher, should you decide to permit this. Even further beyond the potential impact at school, the app could help in the diagnosis of this disorder for future families that will struggle with this disorder.

**Reimbursements**

Your son/daughter will not be provided with any payment to take part in the research.

**Confidentiality**

Your and your child’s confidentiality is our foremost concern. I will not be sharing any information outside of the research team. All information collected from this research will be kept confidential. Any information that is directly relatable to your or your child or your child’s teacher (with permission) will be kept in a digital safe and no-one but the researcher will be able to view it. Only the researcher will know what number your child is and that information will also be kept in a digital safe, with no-one other than the researcher knowing the combination.

**Sharing of Research Findings**

At the end of the study, I will be sharing what I have learnt with the participants and with the community. I will do this by first meeting with the participants then as a presentation to a larger portion of the community. Nothing that can be directly linked to your or your child will be presented. The results will additionally be published to the Library and Archives Canada – Theses Canada website

**Right to refuse or withdraw**

You may choose to not allow your child to participate and your child does not have to take part in this research if they do not wish to do so. Your decision to participate or not will not affect your, nor your child’s future in any way. Additionally, you or your child may decide to stop participating at any time, and this decision will not affect your, nor your child’s future in any way.

**Who to Contact**
If you have any questions, you may ask them at any time, even after the research has started. I can be contacted at or on my cell phone at

Part II: Certificate of Consent

Certificate of Consent

I have read the foregoing information, or it has been read to me. I have had the opportunity to ask questions about it and any questions that I have asked have been answered to my satisfaction. I consent voluntarily for my child to participate as a participant in this study.

Print Name of Parent or Guardian __________________

Signature of Parent of Guardian___________________

Print Name of Child __________________

Signature of Child___________________________

Date ___________________________

Day/month/year

Statement by the researcher/person taking consent

I have accurately read out the information sheet to the parent of the potential participant, and to the best of my ability made sure that the person understands the document and research.

I confirm that the parent was given an opportunity to ask questions about the study, and all the questions asked by him/her have been answered correctly and to the best of my ability. I confirm that the individual has not been coerced into giving consent, and the consent has been given freely and voluntarily.
A copy of this Informed Consent Form has been provided to the parent or guardian of the participant ____

Print Name of Researcher/person taking the consent______________________________

Informed Consent Form adapted from the World Health Organization’s” Informed Parental Consent for Research Involving Children (qualitative)” template (2014).

References

Appendix C – Post-Intervention Interview

Post-Technological intervention, Semi-Structured Interview

The post-technological intervention, semi-structured interview will be in a face-to-face format at the interviewee’s home, or other mutually agreed upon meeting place, and scheduled consecutive to the technological intervention. This allows all participants the full opportunity to complete the technological intervention prior to providing their responses. This will allow for a more informed and better articulated response from the participants. Since the post-technological intervention interview questions are predominately qualitative, the researcher is trying to understand how the student ‘felt’ about the technological intervention and what, if any, changes to their lives outside the technological intervention.

Interviewer Notes

Italicized texts are question-specific notes or additional probing questions the interviewer may use. These questions are not meant to be final, rather a starting point, and the interviewer is encouraged to continue the use of probing questions until an appropriate amount of detail is achieved. As cautioned by Kalof et al (2008), “be sure to ask follow-up questions to clarify any confusing or contradictory statements that respondents make,” (pg. 128).

For questions three and four, attentiveness and distractibility are not meant as opposites, since both can occur at the same time. For example, the child may be able to stay on task, yet not able to control distractions. In this context, attentiveness means the child’s ability to stay on task, while distractibility means the child’s ability or lack thereof, to block out distractions.
Once again, the question structure has the question followed by the type of expected response, in brackets.

**Post-Technological intervention, Semi-Structured Interview Questions**

**Quality of the technological intervention questions**

1. What was your favourite part of the technological intervention? (open-ended)

   Continue to probe... for example, if the student says they enjoyed the hidden games; ask them, “How many different games did you find?” (Number of games (x) to be determined) or “Of the (x) games, which one was your favourite; which one was your least favourite?” The goal here is to put the child at ease but the responses can be additionally used for future improvements to the tool.

2. What did you not like about the technological intervention? (open-ended)

   Continue to probe... for example, if the student says they did not enjoy the chosen activities; ask them, “What activities would they have preferred?” As with the previous question, the goal here is to put the child at ease. These responses can also be used for future improvements to the tool.

**Attention and distractibility questions**

3. Did you notice a change in your how well you could keep focused? (Yes/No)

   a. If yes;

      i. Please describe (open-ended)

         Continue to probe... for example, if the student indicates they were able to concentrate more on finishing their task, ask them, “How did that make you feel?” or “What other tasks do you feel you could accomplish?”
ii. On a scale of one to ten, where one is no change at all and ten is an extreme change, how would you rate the change overall? (1-10)

4. Did you notice a change in how you handled distractions? (Yes/No)
   a. If yes;
      i. Please describe (open-ended)
      
      *Continue to probe... for example, if the student indicates they were able to filter or block-out the distractions, ask them, “Do you think this will help you in other areas of your everyday life? If yes, what are those other areas?”*

      ii. On a scale of one to ten, where one is no change at all and ten is an extreme change, how would you rate the change overall? (1-10)

**Behavioural questions**

5. Did you notice any other positive changes in behaviour? (Yes/No)
   a. If yes, please describe (open-ended)
      
      *Continue to probe... for example, if the student indicates they were able to get their chores done quicker, ask them, “What are some of the other things you can do quicker?”*

6. Did you notice any negative change in behaviour? (Yes/No)
   a. If yes, please describe (open-ended)
      
      *Continue to probe... for example, if the student indicates they felt anxious, ask them, “What do you think the cause is?” or “Do you feel it was part or parts of the technological intervention that made you feel that way?” and “If yes, what*
part or parts?” Again, these responses will be used for future iterations of the tool.

7. If you could make changes to the technological intervention, what would those changes be? (open-ended)
   
   a. Why would you make these changes? (open-ended)

   Continue to probe... If the student is unable to fully explain why they think a change is warranted, it may not be. Lead them to their own answer so they understand why it may or may not be a good idea.

8. On a scale of one to ten, where one is not effective at all and ten is extremely effective, how would you rate the overall experience? (1-10)

9. Do you have any questions, comments, or concerns that we have not yet discussed? (Yes/No)
   
   a. What would those be? (open-ended)

References

Appendix D – Tables

Tables

Column headers in the following table are as follows: Phase indicates which phase the data were recorded for, Date indicates which date the data were recorded on, AQ indicates the calculated AQ for the specific date, DQ indicates the calculated DQ for the specific date, DTT (Daily Total Time) indicates how much time the participant used the app for the specific date, and #D indicates the number of distractions for the specific date. DTT was calculated by using this formula: Daily End Time – daily End Time = DTT. The formula for #D the total record count. Finally, the calculations for AQ and DQ were discussed in the technological intervention section and are in a minute:second.thousandths format (mm:ss.000). It is important to note that calculated values above are derived from the entire raw data for that particular day. No records were removed and the data were not scrubbed in any way.
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Appendix E – Figures

Figures

Figure 1

![Diagram showing interconnections between Reading Comprehension and ADHD, Learning Theories, and Technology with Technological Intervention for Students with ADHD]

Figure 2
A brief explanation of the graph components for the following four pages. The X axis are dates with the Y axis being time duration in a minute:second.thousandths format (mm:ss.000). The data points are the AQ, represented by diamond-style markers and DQ, represented by circle-style markers, calculations for that specific date with the black connecting-line representing AQ and the grey connecting-line representing DQ. The dotted black line indicates the trend for AQ if the intervention were to continue and the dotted grey line indicates the trend for DQ if the intervention were to continue.
ON-TASK: INCREASING ATTENTIVENESS IN STUDENTS WITH ADHD

Figure 3

Figure 4
Figure 5

P2 (A-06) Phase 1 Combined Daily Results

Figure 6

P2 (A-06) Phase 2 Combined Daily Results
ON-TASK: INCREASING ATTENTIVENESS IN STUDENTS WITH ADHD

Figure 7

![Figure 7 Image]

Figure 8

![Figure 8 Image]
Figure 9

P4 (A-11) Phase 1 Combined Daily Results

Figure 10

P4 (A-11) Phase 2 Combined Daily Results
Appendix F – P1 (A-02) Semi-Structured Interview Transcript

A-02 - Semi-Structured Interview Questions and Responses.

Immediately prior to the interview, the results from the technological intervention were discussed and explained. At the outset of the interview the participant seemed very at ease yet ready to answer any questions I posed him. Mom sat away from myself and the participant and I was concerned that she wasn’t going to answer any questions during the interview.

ME- “What was your favourite part of the experiment?”

P- “I think being able to choose the tests. I also liked being able to level up.”

M- “Did you like that, [P]?”

Mom immediately started providing input.

P- “Yeah, I really liked that!”

ME- “What did you not like about the experiment?”

P- “I noticed a fair bit of science and math tests that we haven’t taken those topics in school yet.”

I noticed his concern more towards the 3rd party testing content than towards the app. I continued to question about this.

ME- “Well, not so much about the tests, those are outside of this research, but more about the app itself. The tests are from an outside company. For example, I know there were some bugs in the app.”
P- “Yeah, like when I was looking directly at the iPad, it would buzz for no reason.”

ME- “Did you like that?”

P- “Not at all.”

ME- “So would you say that the bugs were something you didn’t like about the experiment?”

P- “Yes, I would say that.”

There was a certain amount of disdain in his voice when talking about the bugs; I could tell they made it hard for him to use the app. Not wanting to change his demeanor towards the interview, I immediately switched to another topic.

ME- “Using the app, or even outside of the app, did you notice your attention change? Did you feel like you had more attention?”

P- “Yes.”

ME- “Can you explain a bit more?”

P- “I felt like I was looking a bit more. Like paying more attention.”

ME- “Did you feel more and more like you were staying on task?”

P- “Yeah.”

ME- (referencing the results from the technological intervention) “… and I can see that in the numbers as well. So you said you felt like you were more attentive, on a scale of one to
ten, where one is no change at all and ten is an extreme change, how would you rate the change overall? From the start of using the app to the end?”

P- “I’d say a 5 or a 6.”

During this question, the participant was very attentive, perched at the edge of his seat, almost as if a distraction was waiting to take him away. I continued with my questions.

ME- “So what about the bad side, like distractions… Did it [the app] bring you back on task? Did you notice any change in distractibility?”

P- “Yeah! (emphatically). The flashing lights and buzzing, I thought, meh, I should probably go back to the iPad just to shut it up. And also, I wanted to do the test as well. The lights brought me back.”

ME- “You didn’t want to be distracted… it just kind of happens.”

P- “Yeah.”

ME- “Did you feel less distracted? Were you able to realize the distraction and…”

P- “…and shut it out?”

At this point, the participant anticipated my question and answered before I could ask it.

ME- “Yes, shut it out and stay focused on task?”

P- “More and more.”

Wanting to better understand what this meant, I continued to probe.
ME- “More and more… as time went on?”

P- “Yes. It was kind of like, ‘oh, I already looked at that. I can look at that another time; let’s focus on this.”

ME- “That’s great! Good job! So, on a scale of one to ten, where one is no change at all and ten is an extreme change, how would you rate the change overall?”

P- “I’d give this one a 7.”

ME- “Great. So, did you notice any other positive changes in behaviour?”

P- “In school (emphasis). I found myself focusing more.”

ME- “Focusing more?”

P- “It was easier to work; stay on task.”

ME- “Easier to block stuff out?”

P- “Yes.”

ME- “So we’ve talked about good changes in behaviour, did you notice any negative change in behaviour?”

P- “No.”

ME- “Were you nervous at all… like did you feel any anxiety?”

P- “No. I didn’t notice any anxiety at all. It was more like, ‘do I have to?’”
ME- “Were you frustrated at all?”

P- “No.”

ME- “Did you feel anything negative?”

P- “No.”

At this point, mom started to engage more. Remaining relatively quiet for the first few questions, she was then ready to help clarify some of the participant’s statements as well as provide input of her own.

M- “I noticed things… like things in the beginning. For the first week, it was really hard to motivate you [P] to do the half hour, but once the thing started buzzing, you became more into it when you were getting the buzzing feedback. The first day or two were fine, but after that, it was like, ‘oh man, do I have to do this?’ and I said, yes, you made a commitment; you have to do this. There were a few times near the end, and this became an issue for us, when our schedule really filled up and with band practice, soccer, school and travelling back and forth he simply couldn’t do it.”

P- “… and I couldn’t do it.”

M- “I asked him to use it in the car while we were travelling but the app needed Wi-Fi. So, I just wanted to say that that made a really huge difference for us. If we could have done it in the car, or away from the house, he would have used it a lot (emphasis) more. Like in the beginning, you [P] were like, 30 minutes, and you [P] were like, ‘I’ll just do the PE ones’, but
without getting the immediate reward he wasn’t into it, but once started buzzing, or doing whatever it was that it did, that really helped him.”

ME- “So there was no negative behaviour as a result of the intervention? No lashing out at his sister or anything?”

M- “Oh, no… not at all (emphasis)”

As mom was answering the question, the participant started to get restless, agitated. Not wanting to lose him to his disorder and returning to the question, I asked:

ME- “If you could make changes to the experiment, what would those changes be?”

P- “If you could let me pick my own questions for the tests, that would be great. I’d like to be able to pick the questions for tests in the future.”

Again, trying to steer the participant away from material that was not being researched, I asked:

ME- “But more on a higher level, for example, the next version of the app will allow you to use any other app, not just websites. So if you have a specific app from your school, you can use it, and not be stuck having to go to websites. This means you won’t necessarily need that Wi-Fi connection to still use the app.”

P- “Oh, that would really help (emphasis). With us living out of town, sometimes we don’t get home until late at night, then there’s homework, there’s supper.”

M- “Is there anything else you would like to see in it? Like, would you like to listen to music?”
P- “That would be cool to listen to music!” (emphasis)

ME- “So you would like to listen to music while you study?”

P- “Yeah, but it would be like pre-programmed into the app, like elevator music. I think, personally, the reason people get distracted is because there’s nothing, I guess, holding them to the app. Does that make sense?”

ME- “Yes, that makes perfect sense!”

P- “There’s nothing like ‘Hey! Look at me!’”

With the participant re-engaged and less agitated I was able to continue with the remainder of the interview.

ME- “Ok, so on a scale of one to ten, where one is not effective at all and ten is extremely effective, how would you rate the overall experience?”

P- “8”

ME- “So you had a great experience?”

P- “Definitely an 8”

At this point the participant was fully engaged and not distracted. I got the feeling that his evaluation of the technological intervention was honest.

ME- “So to wrap things up, do you have any questions, comments, or concerns that we have not yet discussed?”
P- “So, if this does come out, do we get anything?”

ME- “Unfortunately, no. Do you remember when you signed up and we discussed that you wouldn’t get anything for helping me out?”

P- “Yeah, but it was worth the try” (chuckle)

ME- “That it was. Well, thank you so much for your help through all of this. I know it probably wasn’t very easy for you to stick through it, but I really do appreciate all of your hard work in helping me collect my data.”
Appendix G – P2 (A-06) Semi-Structured Interview Transcript

A-06 - Semi-Structured Interview Questions and Responses.

ME- “So, thank you again for all of your hard work. Let’s get started. What was your favourite part of the experiment?”

P- “I liked the rewards because it kind of like made you want to do it more. It kind of motivated you to do it more, like ‘Keep it up’, ‘Good Job’, ‘You’re almost there’.

ME- “OK, that’s great. What did you not like about the experiment?”

P- “The flashing and the noise it made. Like, I would have to turn the volume off because it would be so [emphasis] annoying.”

Having heard about the bugs in the app on previous occasions, I encouraged him to postulate about the app without issues.

ME- “What if the app wasn’t doing it at the wrong time? If it didn’t have those problems, those bugs, would it still be that annoying, or would it be what you need to bring you back on task?”

P- “That would have been better.”

M- “Well, [P], it was effective for sure and I don’t think anything else would have been that effective.”

During the time that mom was discussing with the participant, I checked the recording levels of the mic and it was capturing her voice adequately.
P- “Yeah, I agree. If it’s annoying, you want to look back at it to make it stop.”

ME- “Did you notice a change in attentiveness?”

P- “Yes. I really noticed that once I started to level up that I was more focused. I made it all the way to level 100 then the app died. It wouldn’t let me level up any more and was flashing all the time.”

ME- “So even with all of the issues you found, on a scale of one to ten, where one is no change at all and ten is an extreme change, how would you rate the change overall?”

P- “Maybe a 4.5.”

ME- “A four and a half? OK.”

ME- “Did you notice a change in distractibility?”

P- “Yes, but it wasn’t as severe. Because recently, when we haven’t been doing it, I really notice I’m more distracted than when I was using the app.”

ME- So, keeping this in mind, on a scale of one to ten, where one is no change at all and ten is an extreme change, how would you rate the change overall?”

M- “I think he did better on that.”

ME- “How did [P]’s ability to block out distractions change over the course of the intervention or was there a change?”

M- “I don’t know; this is actually hard. What do you think, [P], about distractions; what did you feel?”
P- “I think I was kind of more focused on that; I could just kind of shut everything out.”

M- “Towards the end, we were really trying to distract him as much as possible. [D] and I would be talking really loud, and yelling to each other from one room to another; we were really trying to make it hard for him, but he did really good. I’d say a 6 for change.”

Towards the end of this response, I could see the participant becoming agitated, as did his mother. At this point, she answered for him with him nodding his agreement.

ME- “Did you notice any other positive changes in behaviour?”

P- “I didn’t notice anything.”

D- “I did notice something, [P], that your behaviour is actually getting a bit worse since you stopped using it. I think having the time right before bed that he [P] needed to stay focused drained him somehow and took away from the excess he had before and made it easier to get him to bed.”

Initially remaining silent, I was delighted to see the participants father providing his input.

M- “Oh, yeah… that’s right!”

D- “Recently, it’s been hard getting him off to bed. Since he’s not been using the app, he’s not draining that pool and has extra energy. He’s just hyper and crazy. Maybe since he’s not focusing on the app anymore, he has nowhere to use up that energy.”

M- “He’s been much harder to get into bed, get his face washed, get his teeth brushed than during the time that he was using the app.”
ME- “Did you notice any negative change in behaviour?”

M- “Not because of what the app is supposed to do, just… This one here [P] had kind of a mini-meltdown because his app was really bad. We had to re-install a couple of times because it wasn’t working and when it was working, it was buzzing and flashing when he was looking right at it. He was just very angry and explosive. This wasn’t because of the app, but because we were waiting until the end of the day when his meds had worn off for your [ME] data collection phase. If I was using this normally, to help him, I would be using it in the middle of the day when his meds could help him to learn to be more attentive. I think this, in conjunction with the meds, would be amazing!” [emphasis].

Noticing the participants lack of attention and subsequent lack of response to the previous question, I moved the questioning into an area that would re-engage the participant.

ME- “OK, so If you could make changes to the experiment, what would you change?”

P- “So you would have this like, pixel character, and you could buy clothes for it and…”

ME- “So kind of like Minecraft?”

P- “Yeah, but more like Prodigy and I can buy pets!”

D- “Maybe instead of that annoying buzzer noise, you could have something less irritating?”

M- “I noticed [P] when he would get the buzzer, he would tense up and his heartrate would soar, and then he’d be running on that extra adrenaline and it would take him a bit to calm back down.”
ME- “I’m thinking that if the app was doing what it was supposed to be doing, it would be less annoying. What if I were to make more of a graduated reminder? So something like a ‘tap, tap, tap’ noise, then perhaps a voice reminder, then the buzzer?”

M- “So maybe more ‘points’ or ‘coins’ or whatever the quicker you return to the device.”

After discussing a couple of ways that the app could be improved, it was time to start binging this interview to an end.

ME- “So, given the whole experience, on a scale of one to ten, where one is not effective at all and ten is extremely effective, how would you rate the overall experience?”

M- “I thought it was great.”

D- “Really happy. I’d probably give it a 7-8.”

M- “Yeah, 7-8.”

ME- “OK. Do you have any questions, comments, or concerns that we have not yet discussed?”

M- “No. You’ve been really quick to answer our questions both in person and through email, so no, none really.”

In an effort to remain transparent, the parents had emailed me a couple of times asking specifically about the issues with the app. I answered those in a timely manner and at the time, they had no further questions.

ME- “OK then. Well, thank you very much [P]. I know it was tough and you powered through it, so thank you.”
P- “You’re welcome.”
Appendix H – P3 (A-07) Semi-Structured Interview Transcript

A-07 - Semi-Structured Interview Questions and Responses.

ME- “So thank you for all of your help. I know it wasn’t easy so thank you very much. Shall we start? (nods) OK, so what was your favourite part of the experiment?”

P- “I get to be on the iPad.”

ME- “What didn’t you like about the experiment?”

P- “I really don’t know.”

ME- “Anything at all.”

P- “About the math.”

ME- “Didn’t like the content of the questions?”

P- “Yeah.”

ME- “What about the app itself? So, when it was rewarding you or when it was buzzing you? Was there anything there that you didn’t like?”

P- “Um, some of it.”

ME- “Which part?”

P- “When it kept on flashing.”

ME- “OK. Did you notice a change in how well you could pay attention?”

P- “I didn’t notice that.”
ME- “You didn’t notice that at all?”

P- “No.”

At this point, I noticed very little interaction with the participant and none from the parents. In an effort to illicit more than single-word or very short answers I enlisted the help of the parents.

ME- [to M and D] “What about you guys… did you notice a change in attentiveness? (pause) You are involved in this too…”

M- “Oh, OK”

ME- “Oh, yes, absolutely!”

I tried to set them more at ease and bring them more into the conversation.

M- “Oh, for sure… I definitely noticed as it went on that he was more attentive. For [P] in particular, I thought it would be impossible for him to focus longer, but it was a good motivation. He really didn’t want it to flash, so he’d be sitting there staring at it.”

D- “I definitely noticed he had more determination once he got used to it.”

ME- “OK. So with that in mind, on a scale of one to ten, where one is no change at all and ten is an extreme change, how do you think he did?

D- “I’d say there was a noticeable change.”

M- “hmm, once he got used to it… I’d say 4. I’d say it wasn’t dramatic, but it was visible. At the very beginning, we’d have to lots of verbal reinforcement, just the very first day,”
but then we tried to step back so it could do its thing. There were a lot of issues with the app, but the days that he was able to use it, I’d say a 4.”

Noticing the participants lack of response, I asked him directly, “So did you notice a change in distractibility?”

P- “No… um, Mom?”

M- “I think so; watching you… what do you think [P]? Did you feel like that? Like you could focus on it when you had to?”

ME- “Did you feel like you could block out distractions? Do you think you had a bit more control there?”

P- “Um, yeah, kind of.”

At this point in the interview, the family’s cat knocked something over in the kitchen creating the perfect distraction for someone already pre-disposed to being distracted and the participant left the conversation. I continued and in lieu of the participant, directed my questions to the parents.

ME- “OK, then on a scale of one to ten, where one is no change at all and ten is an extreme change, how do you think he did?”

M- “I’d say maybe a little higher… maybe a 5 or 6. I thought he did a lot better at blocking out the distractions.”

ME- “Did you notice any other positive changes in behaviour?”

M- “I didn’t see any other positive changes in behaviour.”
D- “I’d say that he was more determined to use the app, but there haven’t been recent changes in his medication and we’re noticing changes in his behaviour outside the app. He’s currently under-medicated based on his body weight, so at the end of the day, there’s changes that we’ve noticed, that might influence any positive changes that would come from the app.”

M- “I would say patience though. He probably got better in patience specifically relating to the app in that, the first time it started flashing, he got really frustrated really quickly. Maybe those positive reinforcements kind of helped him to be less irritated by the small things and endure the irritation a little better and be more patient; that determination. I didn’t really expect that of him. He got a lot farther in the program [intervention] that I would have thought he would. I thought he would have ‘checked-out’ earlier, but he stuck in.”

At this point the participant came back into the room and rejoined the group, but it his agitation was clearly visible and his focus was bouncing around the room. In an effort to bring him back into the conversation once again, I asked, “Did you notice any change in school?”

P- “ummm, not really.”

ME- “That’s fine. There’s no right or wrong answer. I’m just trying to better understand how well things worked.”

Getting very brief answers from the participant, I tried to set him at ease. Being very close to the end of my questions, I tried to finish up.

ME- “Did you notice any negative change in behaviour? I know you were frustrated with the buzzing. Did any of that frustration creep into school or was that just part of the app, and you left that at home?”
M- “When you weren’t using the app, did you keep thinking about it buzzing you or was that only when you were using it?”

P- “Just when I was using it.”

Trying to engage the participant more, I changed questions.

ME- “Now the fun part. If you could make changes to the experiment, how would you change it?”

P- “I’d like to get coins to play these games, like video games or something.”

M- “So, like you earn coins to play in an arcade?”

P- “Yeah.”

Once again, another distraction caught hold of the participant and he one again left the conversation leaving his parents to fill in what he could not articulate.

M- “From our perspective, and for him in particular, because there were so few questions for his level, he got bored very quickly. He doesn’t have all the bits together to go through the whole process. To have access something other than those simple tests would be better. There’s plenty of good educational games out there that you could integrate.”

ME- “I’ll definitely look into those.”

When the participant’s mother made the comment, “he doesn’t have all the bits together to go through the whole process,” I got the sentiment that the participant does not function at the same level as his peers. Not wanting to dwell on this I moved on.
ME- “So, on a scale of one to ten, where one is not effective at all and ten is extremely effective, how would you rate the overall experience?”

D- “I’d say a 6 or a 7.”

M- “Yeah, I’d think you’re right [D]… I’d say a 6 or a 7. I was really impressed with how he responded. I really think with [P] the stuff on the screen meant nothing to him; without me actually sitting behind him, which I did, but then it’s me focusing him, and not the app, so it was really tricky. So being able to access different material, and fixing the glitches of course, I just see so much potential for it, for sure. If he was able to change this much, even with all that he was up against, and in that short period of time, I think it was great.”

ME- “That’s great, thank you.”

As the parents were providing their input the participant returned from another room to join the group for the final question.

ME- “Just to finish up, do you have any questions, comments, or concerns that we have not talked about?”

P- “No.”

M- “No, I think we’re good.”

ME- “Then thank you again. [to P] You were a big help!”

P- (smile).
Appendix I – P4 (A-11) Semi-Structured Interview Transcript

A-11 - Semi-Structured Interview Questions and Responses.

ME- “So thank you for taking part in the study. I really do appreciate your effort; I know it must not have been easy so thank you! Let’s get going. What was your favourite part of the experiment?”

P- “I really liked the buzzing. For the first week I was like, what does this thing do, but then it kicked in and it was really cool.”

I found it interesting that this participant enjoyed the punitive portion of the technological intervention above all else.

ME- (chuckle) “OK. What did you not like about the experiment?”

P- “The bugs! (emphasis) I’d be like, looking straight at the iPad and it would buzz me. I couldn’t be paying more attention to it!”

D- “I noticed his frustration toward the app when it was buzzing for no reason. The best I could tell him was to try to work through it.”

Trying to separate the issues in the app from other issues, I questioned, “So if the app was functioning properly, and only buzzing you when you should be buzzed, that would make it better?”

P- “Oh, yes… very much.”

D- “I think that would have made things much easier for everyone; him [P], me [D] and you [ME].”
ME- “Did you notice a change in attentiveness?”

P- “A bit I suppose. I mean, I was trying hard to level up so I guess I paid more attention. I did notice a difference in class. I was able to concentrate more in class.”

Wanting to better understand this comment, I continued my questioning.

ME- “So you were able to concentrate more in class? How?”

P- “Like, if there was something going on in the hall, I’d tell myself to ignore it and stay focused. A lot of the times, I was able to do it.”

D- “I noticed a change in his attention span away from the app. When working on school work or projects, you [P] were able to keep working longer before you were drawn away to something. It was a nice change.”

ME- “So, on a scale of one to ten, where one is no change at all and ten is an extreme change, how would you rate the change overall?”

P- “hmm, I’d say 6.”

ME- “OK. Along those same lines, did you notice a change in distractibility?”

P- “I did notice a difference. I was able to block distractions out a bit better. I would start to feel distracted by something and tell myself, I don’t want to look at it; I want to keep looking at the iPad.”

Attempting to clarify and expand, I asked, “So you were able to identify that it was a distraction and then block it out?”
P- “Yes.”

D- “As you [ME] asked, we tried to wait until late in the day when his meds had worn off. We put him in the dining room and had the TV on and for a lot of the times, his sister was running around making noise. We really tried to make it as distracting as we could. I think he did amazingly well to block everything out, or at least as much as he did.”

ME- “So, on that same scale of one to ten, where one is no change at all and ten is an extreme change, how would you rate the change overall?”

P- “hmm… I’d say a 7.”

D- “I’d give you [P] more credit than that. I’d say it would be closer to an 8.”

ME- “OK. Did you notice any other positive changes in behaviour?”

P- “I felt like I was able to concentrate more; I could stay focused more on what I had to do at school. It was also easier to start using the app each night after the first couple of days. The first couple of days, I really didn’t want to use it but I made you [ME] a promise.”

ME- “And I thank you for that.”

D- “For the first little while, it was a chore to get him [P] to start using the app every night. Once it started buzzing and levelling up, he was much more into it. It was amazing how much of a change in motivation there was once the app started doing something we could see.”

ME- “So along with the good there’s the bad. Did you notice any negative change in behaviour?”

P- “I don’t think so…”
D- “No, I don’t think there was anything negative, at least not that I’ve seen.”

ME- “If you could make changes to the experiment, what would you like to see changed or added?

P- “I would add games instead of levelling up. I mean, it was OK at the beginning, but after a while it was like, ‘oh, great… I made it to level 37’. After a while I didn’t really care. A game would have been better.”

ME- “So given everything you’ve experienced using the app, and on that same scale of one to ten, where one is not effective at all and ten is extremely effective, how would you rate the overall experience?”

P- “I’d give it a 7-8. I felt different when I was using it and that made me feel better. I felt like I could concentrate more.”

Wanting to explore this further, I asked, “So you felt better about yourself? Do you mean you had more self-esteem from using the app?”

P- “Uh, yeah… I guess so. I mean, knowing I was getting better at concentrating, I felt like I could concentrate more.”

In an effort to clarify, I paraphrased the participant’s comments. “So do you mean, you knew you were getting better because you were getting to higher and higher levels?

P- “Yes and that made me feel good about myself.”

ME- “That’s great! Good for you. So to finish up, do you have any questions, comments, or concerns that we haven’t talked about yet?”
P- “No.”

D- “No, I think you’ve already answered everything. Thanks again.”

ME- “No, thank you; thank you both for all your efforts. They are greatly appreciated.”