Computerized Cognitive Training: From the Laboratory to the Real World

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April 2016

A thesis submitted to McGill University in partial fulfillment of the requirements of the degree of Master of Science

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Preface

The present thesis contains two original manuscripts representing the scope of my Master's research.

My thesis research centers on demonstrating that exercises targeting the development and rehearsal of attentional skills have the potential to improve other related cognitive functions, such as working memory and inhibition of responses, as well as to enhance behavioural and emotional regulation. This thesis begins with an experimental study embedded in the Clinical Neuroscience and Applied Cognition Laboratory, and construes attention training to be a form of cognitive enhancement and treatment approach for healthy children and children with behavioural disorders, such as attention-deficit hyperactivity disorder, oppositional defiant disorder and conduct disorder (Manuscript 1).

As a result of the popularity of the highly profitable brain training market, the second part of my thesis critically reviews the legal aspects of brain training programs. We sketch the extant evidence and discuss ongoing claims in the industry of brain training, aggressive marketing practices, conflicts of interests in scientifically proven studies and the guidelines behind them (Manuscript 2).

Contribution of authors

Manuscript 1: *Attention Training in Children*

Jenilee-Sarah Napoleon: Leading and organizing the research effort for the past two years, data collection and analysis, interpretation of results, and writing of manuscript.

Claire Champigny: Responsible for carrying out a portion of the research, and for adding measures of working memory and attention.

Sheida Rabipour: In charge of the initial research effort and providing guidance.

Elena Perez-Hernandez: Initial study conception.

Amir Raz: Corresponding author, supervising the research process, commenting on the manuscript and providing guidance.

Manuscript 2: *Legal Aspects of Brain Training*

Jenilee-Sarah Napoleon: Primary author, writing the manuscript.

Amir Raz: Corresponding author, supervising the research process, editing and commenting on the manuscript and providing direction and guidance.

Abstract

Cognitive training, typically administered in a computerized manner, is engrained in cognitive rehabilitation and relies on the concept that direct training can lead to a reorganization of neural functions. Neuroplasticity allows brain maps to continually change as a result of experience. Consequently, cognitive training has the potential to diminish cognitive and behavioural dysfunctions and to become a new treatment option for both children and adults. Since children display increased plasticity, the developing brain is more susceptible to interventions. Despite a lack of consensus concerning the effectiveness of cognitive training, a number of findings have demonstrated effects on verbal and nonverbal intelligence, working memory, and academic capacities. The following experimental study examines the possibility for a computerized attention training program to yield significant improvements on neuropsychological measures and behaviour, in healthy children and children with behavioural disorders. The subsequent critical review discusses the highly influential brain training market, and reviews cognitive training programs, advertising approaches, and the legal norms that apply to them.

Keywords: *cognitive training, attention, neuroplasticity*

Résumé

L’entraînement cognitif, généralement administré de manière informatisée, est enraciné dans la réhabilitation cognitive et repose sur le concept que la formation directe peut conduire à une réorganisation des fonctions neuronales. La neuroplasticité permet à l’anatomie et le fonctionnement du cerveau de continuellement changer, suite à l'expérience. Par conséquent, l'entraînement cognitif a le potentiel de diminuer les dysfonctionnements cognitifs et comportementaux et à devenir une nouvelle option de traitement pour les enfants et les adultes. Puisque les enfants en développement ont une plasticité accrue, le cerveau est plus vulnérable aux interventions. Malgré l'absence de consensus sur l'efficacité de l'entraînement cognitif, un certain nombre de conclusions ont démontré des effets sur l'intelligence verbale et non verbale, la mémoire de travail, et les capacités académiques. L'étude expérimentale qui suit examine la possibilité qu’un programme d’entraînement d'attention informatisé puisse produire des améliorations significatives sur les mesures neuropsychologiques et sur le comportement, chez les enfants en santé et les enfants ayant des troubles de comportement. L'essai critique ultérieure aborde le marché très influent de l’entraînement du cerveau, dans lequel nous révisons les programmes d'entraînement cognitif, leurs approches de publicité et ainsi que les normes juridiques sur lesquelles ils se reposent.

Mots-clés: *entraînement cognitif, attention, neuroplasticité*

Acknowledgments

This thesis would not have been possible without the invaluable feedback, guidance, and enthusiasm from my supervisor, Dr. Amir Raz. No amount of words can adequately depict how thankful I am for the past few years. You allowed me to grow both academically and interpersonally. Thank you for believing in me.

I would also like to thank Claire Champigny for being an amazing mentor and pillar – your tireless help means the world. Many thanks to Sheida Rabipour and Mathieu Landry for their guidance, and vital help with data analysis.

I am grateful for my attention trainers: Vanessa, Daphné, Rémi, Jennifer, Clemence, Brennan, and Raveena – without you this project would not have been possible.

Additional recognitions to all of the students in the Raz Lab, you are all so great, I love our dynamic! Liana, Claire, and Rebecca – I am so happy I got to join your office, I could not have picked better mates. Moriah and Michael, thank you for your constructive and witty editorial comments on my drafts.

Lastly, I would like to thank Matthieu, my family, and friends for their unending encouragement throughout this process.

I dedicate this thesis to my mother, Gertrude, you are my rock.

Manuscript 1: Experimental study

Attention Training in Children

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Abstract

Computerized brain training interventions are increasing in popularity. The development of working memory was once believed to follow a fixed trajectory that was not amenable to experience after early childhood; however, studies have refuted these earlier beliefs, finding significant evidence for plasticity in this cognitive domain. Scientists have since then studied brain training as a nonpharmacological approach closely related to cognitive functions such as reasoning ability, inhibitory control and attention. While attention training interventions have been shown to benefit children with attention and behavioural impairments, we were interested in investigating whether transfer effects could be observed in healthy children. The current study examined the impact of a four-week ten-session intervention designed to improve executive functioning, verbal and nonverbal measures of intelligence, working memory, and behaviour of healthy children as well as children with behavioural and attentional disabilities. Participants in the intervention group improved on objective measures of verbal fluency, concentrated attention, working memory, verbal and nonverbal intelligence, and some aspects of behaviour, as reported through subjective questionnaires. Although these findings provide evidence regarding the efficacy of the computerized attention training program, additional research is needed to determine how brain training generalizes to performance in everyday tasks.

Keywords: *brain training, attention training, working memory, behavioural disorders, nonpharmacological treatment*

Abbreviations: ADHD: attention-deficit hyperactivity disorder; ODD: oppositional defiant disorder; CD: conduct disorder

Introduction

The discovery that the human brain is malleable to experience prompted the revolution of computerized brain training (Park & Bischof, 2013). This uprising led to increase interest in developing training program that improve task performance or even lead to transfer effects on cognitive skills beyond the tasks that were trained (Schwarb, Nail & Schumacher, 2016). Despite the enthusiasm around cognitive training, the debate regarding the effects of brain training is still open as the efficacy of these programs is inconsistent. Many studies show positive effects of brain training on global functioning (e.g., Chein & Morrison, 2010; Green & Bavelier, 2003; Jaeggi, Buschkuehl, Jonides & Perrig, 2008; Jaeggi, Studer-Luethi, Buschkuehl, Su, Jonides & Perrig, 2010b), whereas some scientists question the effectiveness of brain training and conclude that there is no convincing evidence of the generalization of the improvements to other skills (e.g., Boot, Kramer, Simons, Fabiani & Gratton, 2008; Owen et al., 2010; Redick, Shipstead, Harrison, Hicks, Fried & Hambrick, 2012; Melby-Lervåg & Hulme, 2013).

The present study examines the benefits and limits of a four-week computerized attention training program on a number of cognitive measures which include executive attention, working memory, verbal fluency, verbal and nonverbal intelligence, and behaviour. This investigation focused on healthy children in addition to children diagnosed with behavioural disorders. In this manuscript, we start by discussing neuroplasticity before discussing attention networks and behavioural disorders along with their effects on executive attention. Next, we cover the development of attention training as a specific form of cognitive training. We then examine the nature and purpose of the present study. We introduce our methodology, including participants, measures, and training program. Finally, we analyze our results, consider the limitations of the study design and organisation, and discuss potential implications.

Brain Plasticity

Brain plasticity, or neuroplasticity, is a broad term for the property of the human brain to adjust to environmental pressure, experiences, and challenges (Seitz, Hung, Knorr, Tellman, Herzog, & Freund, 1995; Johansson, 2000; Johansson, 2004; Pascual-Leone, Amedi, Fregni, & Merabet, 2005; Nithianantharajah, & Hannan, 2006). It takes place at numerous levels from molecules to cortical reorganization (Johansson, 2011). Until the discovery of neuroplasticity, the cortical reorganization of brain maps was discussed only as an abstraction. For example, scientists once considered attention to be an innate and static ability, separate from the characteristics of the brain. Specific hypotheses concerning cognitive development were expressed in terms of internal mental representations and learning experiences rather than innate characteristics of the brain or the effects of experience on the brain (Posner, Rothbart & Farah, 2001, pg.26). Conversely, there has been a recent uprising in the scientific community to view attention as a neural function that is responsive to training (Posner, 1993; Posner & Petersen, 1990; Posner & Snyder, 1975; Raz & Buhle, 2006). Individuals have a high capacity to learn; it is now accepted that plasticity is a normal occurrence and brain maps are always changing (Doidge, 2007, pg.61). For instance, in an influential study in 1995, Elbert and colleagues investigated somatosensory evoked magnetic fields in string players. Their analyses showed that the cortical representation of the digits of the left hand ("the fingering hand") was bigger in these musicians than in controls. When it comes to the right hand, in which no independent movements of the fingers are necessary in string players, they did not observe differences between instrumentalists and controls. Even though there are unquestionably gradients in the ability to learn as a result of intrinsic factors such as age and personal genetic predispositions, nearly all humans demonstrate the ability to acquire new skills and to modify behaviour given suitable training (Bavelier, Green, Pouget, & Schrater, 2012). Our new knowledge of the neural bases of cognition in the mature end-state and neurobiological models of development can guide our investigations of cognitive development in children.

Attention Networks

Attention can be either maintained, or shifted to meet the ever-changing demands of daily life (Ruff & Rothbart, 1996, pg. 26). Posner and colleagues have proposed one of the most influential frameworks by which to comprehend attention based on neuroanatomical and neuroimaging data. This model suggests that attention contains three major functions: alerting, orienting, and executive control, related to specific neuroanatomical networks (i.e., different networks of interconnected brain areas). The alerting network is involved in establishing an attentive state and maintaining readiness to react. Imaging studies illustrate that the alerting network depends largely on frontal and parietal areas of the right hemisphere (Coull, Frith, Frachowiack & Grasby, 1996; Posner & Petersen, 1990). Orienting implicates selectively focusing on one or two items out of many possible inputs. The orienting networks utilizes superior and inferior parts of the parietal lobe in conjunction with frontal and subcortical structures related to eye movements (Corbetta, Kincade, Ollinger, McAvoy & Shulman, 2000). The executive control network has been associated to working memory (the mechanisms and processes that are implicated in the control, regulation and maintenance of information), as well as to the control of goal-directed behaviour, target detection, error detection, conflict resolution, and inhibition of automatic responses. The concept of central executive functions is usually introduced to account for how we modulate concentration and allocate attention and effort. Executive or high level control may be described as the process of determining which goals have the highest priority and controlling the nature, sequence, and timing of actions to meet those goals (Ruff & Rothbart, 1996, pg. 28) and plan for complex sequential activity. These functions are attributed to the frontal cortex (Stuss & Benson, 1984); they involve frontal areas including the anterior cingulate and lateral prefrontal cortex (see Figure 1 for visualization of the three attention networks as revealed by fMRI). Each of these neuroanatomical networks appears to undergo strong postnatal growth (Ruff & Rothbart, 1996).

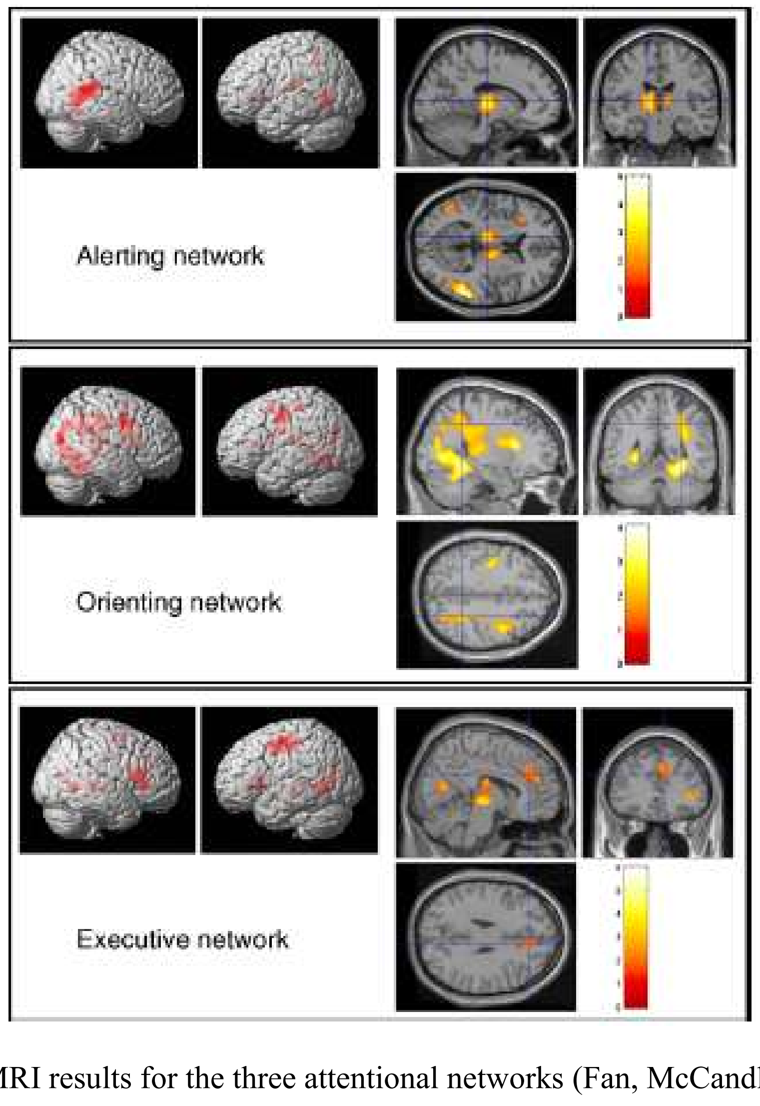

Figure 1. fMRI results for the three attentional networks (Fan, McCandliss, Fossella, Flombaum, & Posner, 2005).

Working Memory

Working Memory, a domain of Executive Function, has been demonstrated to play a crucial role in sustaining attention, goal attainment, and learning (Green et al., 2012). The term 'working memory' is used to refer to a limited capacity system that allows the temporary storage and handling of information necessary for complex tasks such as learning, reasoning and comprehension (Baddeley, 2000). It is also often described as the ability to hold in mind and manipulate small amounts of information for brief periods of time. It is a crucial requirement for many everyday tasks and is considered a critical influence on educational development during childhood (Gathercole et al., 2013). In determining individual differences in working memory span, executive processes are the principal factors. In working memory span tasks, subjects are required to combine processing and storage simultaneously (Baddeley, 2003). For instance, a working memory task may have a participant read out a series of sentences while required to remember the last word in each sentence (Baddeley, 2003). Measures of working memory capacity depict a significant relationship with performance in many academic abilities, including reading comprehension, written expression, problem-solving, and mathematical reasoning (Gathercole, Alloway, Willis & Adams, 2006; Swanson & O'Connor, 2009). Given the multitude of activities possible at any given time, control and organization of behaviour are essential. Research has demonstrated that persons with behavioural disorders tend to show specific deficits in these functions, particularly in executive control (Swanson et al, 1998), which in turn may hinder learning outcomes and result in academic underachievement.

Behavioural Disorders

Behavioural disorders involve persistent problems in one's ability to control his or her emotions and behaviours (Aboujaoude & Koran, 2010). This lack of self-control causes individuals suffering from these disorders to experience significant distress or impairment in many areas of functioning, such as disruptions in social, personal, familial, and educational aspects of their lives. Some of the most prevalent forms of behavioural disorders in childhood include attention-deficit hyperactivity disorder, oppositional defiant disorder, and conduct disorder (Egger & Angold, 2006).

Attention-deficit hyperactivity disorder (ADHD)

ADHD, one of the most prevalent childhood-onset psychiatric disorders (Hansson Hallerod, Anckarsater, Rastam, & Hansson Scherman, 2015), is a highly co-morbid (Yoshimasu et al., 2012), multifarious, and challenging neurodevelopmental disorder affecting both children and adults (Wolraich & DuPaul, 2010, preface xvii). It is characterized by a persistent or on-going pattern of inattention and/or hyperactivity-impulsivity and includes an array of behaviour, present in numerous settings (e.g., school and home) that can lead to performance issues in social, educational, or extracurricular settings (Sadock, Sadock, & Kaplan, 2010). Individuals with ADHD typically have trouble with impulsivity, organization, maintaining attention (Singh et al., 2010) and executive function – the abilities to focus on one activity and filter out extraneous stimuli, to process information in working memory, to shift attention, and to regulate moods (Wolraich & DuPaul, 2010, pg. 17; APA, 2015). ADHD occurs in approximately three to seven percent of grade-schoolers (Sadock, Sadock, & Kaplan, 2010, pg. 375).

Oppositional Defiant Disorder (ODD)

The DSM-V defines oppositional defiant disorder as a pattern of negativistic, hostile, and defiant behaviour toward authority figures. The disruption in behaviour causes clinically significant impairment in social, academic, or occupational functioning (APA, 2015). It often appears in the preschool years, but initially it can be difficult to differentiate from developmentally appropriate, albeit troublesome, behaviour (Frick & Nigg, 2012). Children who develop a constant pattern of oppositional behaviour during their preschool years are likely to develop oppositional defiant disorder during their elementary school years. They have substantially strained relationships with their parents, teachers, and peers, and have high rates of coexisting conditions such as attention-deficit/hyperactivity disorder and mood disorders. Oppositional defiant disorder often precedes conduct disorder and antisocial personality disorder during adulthood (Sadock, Sadock, & Kaplan, 2010; Burke, Waldman, & Lahey, 2010).

Conduct Disorder (CD)

Conduct disorder is a behavioural and emotional disorder of childhood and adolescence. Children with conduct disorder typically act inappropriately, infringe on the rights of others, and disrupt social norms (Gleason, 2012). It is defined as a repetitive and persistent pattern of behaviour in which the basic rights of others or major age-appropriate societal norms are violated (APA, 2015). The disturbance in behaviour causes clinically significant deficiencies in social, academic, or occupational functioning. These behaviours fall into four main groupings: aggressive conduct that causes or threatens physical harm to other people or animals; nonaggressive conduct that causes property loss or damage; deceitfulness or theft; and serious violations of rules. In childhood-onset conduct disorder, individuals are usually male, frequently display physical aggression toward others, have disturbed peer relationships, may have had oppositional defiant disorder during early childhood, and usually have symptoms that meet full criteria for conduct disorder prior to puberty (Pardini, Frick, & Moffitt, 2010). Many children with this subtype also have concurrent ADHD or other neurodevelopmental difficulties. One-year population prevalence estimates range from 2% to more than 10%, with a median of 4% (Costello, Eggar, & Angold, 2005). The onset of conduct disorder may occur as early as the preschool years (Keenan et al. 2011; Moffitt et al. 2008), but the first significant symptoms usually emerge during the period from middle childhood through middle adolescence (Gleason, 2012).

Behavioural Inhibition and Self-Control

Behavioural inhibition is measured by three interrelated processes: (1) inhibiting the initial prepotent response to an event, (2) stopping an ongoing response or response pattern, thereby permitting a delay in decision to respond or continue responding; and (3) protecting this period of delay and the self-directed responses that occur within it from disruption by competing events and responses (interference control) (Barkley, 2005, pg. 47). Waiting for a desired object, refraining from violence when angry and accomplishing complex tasks in which multiple actions must be executed in proper order are all examples of abilities that become possible only with increasing self-control − any response or chain of responses by the individual which serve to alter the likelihood of their subsequent response to an event and, by doing so, function to modify the likelihood of a later consequence associated to that event (Barkley, 2005, pg. 51; Posner, Rothbart & Farah, 2001, pg.26). As previously mentioned, behavioural inhibition tends to be impaired in children with behavioural disorders. In earlier studies (Oosterlaan et al., 1998), it has been established that children with ADHD, ODD, and CD have slower and more variable response execution processes, as well as slower inhibitory control processes, when compared to normal controls. Some scientists have suggested poor response inhibition to be the core deficiency in behavioural disorders (Scheres, 2002, pg. 27). A meta-analysis revealed poor inhibitory control in ADHD, ODD and CD (Oosterlaan et al., 1998).

Attention Training

Attention training is based on the notion that competence increases after repetitive rehearsal of precise cognitive processes of attention (Posner & Raichle, 1994) as repetition produces adaptations in the basic neuroanatomical networks related to these processes (Tamm, McCandliss, Liang, Wigal, Posner & Swanson, 2007). It refers to activities that modify the brain in a way that increases cognition, and performance in areas beyond those involved in the training (Tang & Posner, *in press*). Training programs that directly target working memory provide important evidence that it is possible to make lasting changes to these memory capacities (Holmes & Gathercole, 2013). Findings have also demonstrated that teacher-administered training leads to widespread and strong gains in working memory and scholastically significant improvements in academic performance using this skill, such as mathematical problem solving and reading comprehension (Shaley, Tisal & Mevorach, 2007; Holmes & Gathercole, 2013).

Attention training uses constant computer feedback to emphasize correct responses. Research findings have illustrated that the exhaustive practice of specific cognitive activities can result in task performance benefits that transfer to similarly structured but untrained tasks (Holmes et al., 2009; Dunning et al., 2013; Astle, Barnes, Barker, Colclough, & Woolrich, 2015), hence training attention and working memory. It was shown to diminish parent-and teacher rated symptoms of ADHD (Klinberg et al., 2005) and alter the connectivity between frontoparietal networks and both lateral occipital complex and inferior temporal cortex (Astle, Barnes, Barker, Colclough, & Woolrich, 2015).

Using a version of attention training, scientists designed a study to adaptively test children in tasks that required sustained attention, selective attention, spatial orienting, resolving conflict, and dual task management (Shalev, Tsal, & Mevorach, 2007). Parental rating scores for the group that underwent attention training were reduced for ratings of inattention (by 23%) and hyperactivity (by 19%). Researchers have also suggested that attention training in preschool-aged children may have a long term influence on the functional development of these systems. They claim that implementing attention training programs with children at risk for development of attention and behaviour difficulties may inhibit or halt impairments of attention (Tamm, McCandliss, Liang, Wigal, Posner & Swanson, 2007). Improvements in functions directly related to working memory, such as following instructions and attention, have been demonstrated with the use of computerized programs (Soderqvist & Bergman Nutley, 2015).

Taken together, these studies provide significant support for the notion that adaptive training of executive function skills and sustained attention skills may positively influence the developing attention skills of elementary school-aged children with behavioural disorders, and that such increases may, under some conditions, generalize to ecologically valid assays of real-world effortful task performance and manifestation of behavioural disorder symptoms (Tamm, McCandliss, Liang, Wigal, Posner & Swanson, 2007).

Although far from conclusive, it does appear that attention can be trained. Further, it seems that attention training can be altered successfully for preschoolers, and has promising evidence as an intervention for children at-risk for or diagnosed with an impulse control disorder. It has been considered as a potential nonpharmacological alternative treatment in the stead of stimulant medication for behavioural disorders and attention based disorders (Tamm, McCandliss, Liang, Wigal, Posner & Swanson, 2007).

While there are few studies investigating the utility of attention training in the ADHD population, published studies provide support for attention training in treating ADHD (Kerns et al., 1999; Klingberg et al., 2005; Klingberg, Forssberg, & Westerberg, 2002; O'Connell, Bellgrove, Dockree, & Robertson, 2006; Semrud-Clikeman et al., 1999; Shalev, Tsal, & Mevorach, 2004; Williams, 1989). Studies of attention training in ADHD not only report improvements in executive functions but also provide initial support for "transfer of training" or generalization effects (Shinaver III, Entwistle & Söderqvist, 2014).

Our Study

The current project, developed based on an adapted version of the program 'Teach-the-Brain' (Rueda, Rothbart, McCandliss, Saccomanno, & Posner, 2005), aimed to clarify how control networks operationalized by attention can regulate cognition, feelings, thought, and behaviour across development. As aforementioned, attention is essential to self-regulation – the ability to manipulate one's own emotions, thoughts, or actions on direction from the self or another person. Inhibition is measured by performance on cognitive and behavioural tasks that require withholding of reacting, delayed responding, termination of ongoing responses, and resisting distraction or disruption of performance by competing events (Barkley, 2005, pg. 48). Attention training is an approach to early child education that places emphasis on improving self-regulation. The goal of this overall project was to study the direct cognitive and indirect overall effects of attention training on healthy children and ones with behavioural problems, such as ADHD, ODD, and CD by using clinical, behavioural and cognitive evidence. We predicted that, after computerized attention training adapted from Rueda et al., (2005) attentional capacity would be associated with improvements in verbal and non-verbal abilities and on behavioural measures, comprising those of executive control. To the best of our knowledge, few studies have developed an early education approach that places emphasis on improving self-regulation in healthy children and children with behavioural disorders.

Game Interventions

Games are increasingly significant instruments for educational and behaviour-change interventions due to their ability to keep players motivated (Baranowski, Buday, Thompson, & Baranowsky, 2008; Erhel & Jamet, 2013). Scientists studied the impact of verbal feedback in stimulating player motivation and future play in a brain-training game (Burgers, Eden, van Engelenburg & Buningh, 2015). Findings revealed that evaluative feedback increases, while comparative feedback decreases future game play. They showed that positive feedback fulfils competence and autonomy needs, thereby boosting intrinsic motivation. It is more powerful in developing long-term motivation and play (Burgers, Eden, van Engelenburg & Buningh, 2015).

Previous research (Johnson, 2013) also showed that evaluative feedback that clearly states both the evaluation (e.g., “you did well”) and the evaluated behaviour (e.g., “you completed level 1”) was effective in improving task performance. For these reasons, this present study included both a computerized attention training intervention, in addition to a motivational component paired with individual evaluative feedback.

Methods

This study was approved by the Research Ethics Committee of the Jewish General Hospital. Informed written consent and child assent forms were obtained from all participants prior to entering the study.

Information given to participants' legal guardians during recruitment indicated that we were conducting a research project exploring claims of improved intelligence and inhibitory control following a new computerized brain-training program. We explained that the training program used age-appropriate computer games to increase attention and that with their collaboration and their child's participation, we could develop interventions that could offer the potential benefits associated with the training at no cost. We further indicated that the child's participation was voluntary and that they should not feel any obligation to participate (*see Appendix A for Letter of Invitation*).

Participants

This study's experimental group included 103 children between the ages of 4 and 11 (55 boys; 48 girls; mean age= 7.88 years) whose parents or legal guardians volunteered to participate in the training program. The participants were separated into two groups by diagnosis. We assessed each participant before, immediately after the attention training program and two months following the post assessment.

Recruitment

Recruitment via the Child Psychiatry Department at the SMBD Jewish General Hospital:

Participants were recruited via the Child Psychiatry department at the SMBD Jewish General Hospital in Montreal. If health care professionals were interested in participating, after answering their questions, we asked them to inform parents and legal guardians if they were aware of children who satisfied the inclusion criteria.

All parents and legal guardians were informed that participation was completely voluntary. They were also informed, through the consent form as well as during a personal meeting, that participation, withdrawal, or refusal of involvement in the study would not affect their child's ongoing or future treatments, and that all information would remain confidential. Parents and legal guardians of potential participants were informed that no monetary reward would be provided, but that their child would receive stickers and prizes to thank them for their participation and to encourage them during the sessions.

Recruitment via elementary schools:

Participants were also recruited via private schools in the region of Montreal that showed interest in taking part in the study. We met with school principals, teachers and psychologists to present the project in detail.

Selection of healthy participants:

After the schools showed interest in taking part in the study, teachers gave parents invitation letters, inviting them to participate in our study and allowing the co-investigators to contact them with more information. Once a teacher agreed to take part in the study, he/she was asked to sign the teacher consent form.

Selection of participants with behavioural disorders:

Children who met the inclusion criteria were nominated by the school psychologist. If the school psychologist deemed these selected children appropriate for the study, they were invited to participate. Their parents received invitation letters, inviting them to take part in our study and allowing the co-investigators to contact them with more information.

Recruitment via summer camps:

Participants were also recruited via a summer camp in the region of Montreal that showed interest in taking part in the study. We presented the project to the director of the Westmount Science Camp. Following the confirmation of his interest in the study and after receiving all inscriptions, the director and our team identified all children eligible for our study. He contacted the parents to invite them to participate and sign a short consent form giving us the right to use their child's data in our research. Upon their agreement to participate, the parents were asked to fill out online questionnaires.

Inclusion and exclusion criteria

In order to participate in this study, children could be either without disorder (healthy) or who have been diagnosed with Attention Deficit and Hyperactivity Disorder (ADHD) - (DSM-V), Oppositional Defiance Disorder (ODD) - (DSM-V) or Conduct Disorder - (DSM-V). Children were excluded if they were taking stimulant and/or anti-psychotic medication; diagnosed with an autistic spectrum disorder, epilepsy, Tourette's syndrome or mental retardation; legally blind; and/or deaf.

INCLUSION CRITERIA	EXCLUSION CRITERIA
→ 4 to 11 years of age → Healthy (no mental disorder) → Attention Deficit and Hyperactivity Disorder (ADHD), (DSM-IV-R) → Oppositional Defiance Disorder (ODD) - (DSM-IV-R) → Conduct Disorder - (DSM-IV-R).	→ Autism Spectrum Disorders (ASD). → Epilepsy diagnoses. → Tourette's Syndrome. → Mental retardation. → Currently on psychotic and/or stimulant medication and → Legally blind; and/or deaf.

Table 1. Inclusion and Exclusion Criteria

Location

The assessment sessions and the computer training session were held in a child-friendly room at the Clinical Neuroscience and Applied Cognition Laboratory (Jewish General Hospital). For children who had their assessments and sessions done in their schools or summer camps, we asked the schools and camps to provide us with a room to work in.

Procedure at the JGH

If the parent or legal guardians agreed to be contacted, a meeting was arranged where we explained the study in further detail. If they agreed to participate, they were asked to sign the consent form during that time.

If the parent agreed and the child's teacher was at the Jewish General Hospital, he/she was contacted in order to ask for his/her consent to participate in the study. If the child's teacher gave us his/her consent, he/she also completed two online questionnaires. These included questions regarding the child's behaviour in the classroom. The child was not excluded from the study if the teacher decided not to participate.

Assessment procedure at the JGH and at Schools

Each assessment session took approximately one hour. Prior to the inclusion of the child in the study, the parents answered a set of three online questionnaires one to two weeks before the training sessions began. These questionnaires asked for a general background (*See Appendix B for Background Questionnaire*) and the behaviour of their child. Each child completed tasks which measured their attention span and impulsivity, as well as verbal, non-verbal, and memory skills.

During this session the children were introduced to their assigned interventionist ('the attention trainer') who would train and assist them for the duration of the intervention. We also showed the participant a visual timeline of what the training would consist of, allowing them to have a better understanding of what would happen during the next 3-4 weeks.

Training procedure at the JGH and at Schools

The attention training sessions were done during school hours at a set time approved by the therapist and teacher in a manner that would interfere as little as possible with school activities. In some cases, the sessions were done after school hours or during the weekend.

Children at the Westmount Science Camp (healthy)

Assessments and training were done during the child's time at the Westmount Science Camp. Our project was offered as one of the science activities.

Data Collection

We collected behavioural data through online questionnaires given to parents or legal guardians and teachers before and after the end of training sessions. We asked parents or legal guardians to complete the background questionnaire, the Children's Behaviour Questionnaire (CBQ) or the Temperament in Middle Childhood Questionnaire (TMCQ) depending on the child's age (Rothbart & al., 2001), and the Behavioural Assessment System for Children (BASC- II) (Reynolds & Kamphaus, 2004). Teachers also completed the "Teacher Rating Scale" in the BASC-II (Reynolds & Kamphaus, 2004) as well as the CBQ (Rothbart, Ahadi, Hershey, & Fisher, 2001) or the TMCQ, based on child's age.

On the pre, post and long-term assessment days, participants performed on 3 RIST subtests ('Guess What', 'Odd-Item Out", and 'What's Missing'), the d2 test of Concentrated Attention, the Buschke Selective Reminding Test, the Backward Digit Span and the Controlled Oral Word Association Task. Children aged 8 or over were asked to complete a Self-Report version of the BASC-II, using a pen and paper.

Measures

Measures of Attention

D2 Test of Concentrated Attention - The d2 Test of Concentrated Attention (also known as the Concentration Endurance Test), developed by Brickenkamp (1981), is a cancellation test involving simultaneous presentation of visually similar stimuli, which has been proposed as a particularly useful measure of attention and concentration processes (Brickenkamp & Kilmer, 1998). The d2 Test measures processing speed, sustained attention, rule compliance, and quality of performance, allowing for a neuropsychological estimation of individual attention and concentration performance. The task was to cancel out all target characters (a "d" with two dashes), while ignoring "d's with more or less than two dashes, and "p" characters with any number of dashes, in fourteen successive timed trials. The child was asked to mark as many targets per line as possible, with a time limit of 20 seconds per line. The d2 performance subscales exhibit excellent internal consistency (Bates & Lemay, 2003).

Measures of Working Memory

Buschke Selective Reminding Task (BSRT) - The BSRT (Hannay & Levin, 1985, after Buschke, 1973) uses a multi-trial word list learning task to measure verbal memory. It is a test designed to measure verbal learning and memory through the use of a list-learning procedure over multiple trials. Following the first presentation of the list, only the words the child did not recall were repeated on subsequent trials" (Hebben & Milberg, 2002, p. 110). This paradigm is believed to separate verbal memory into distinct processes.

Backward Digit Span (BDS) - The BDS is a subtest of the 3^{rd} edition of the Weschler Adult Intelligence Scale (WAIS-III) and an optional subtest of the 3^{rd} edition of the Weschler Intelligence Scale for Children (WISC-III) (Hebben & Milberg, 2002). In this task, the child repeated digits in the exact reverse order they were presented to them. This test measured mental control and working memory in our sample.

Measures of Intelligence

Reynolds Intellectual Screening Test (RIST) - The RIST consists of subtests originating from the Reynolds Intellectual Assessment Scales (RIAS), a more comprehensive measure of intelligence. It is a brief screening instrument used to assess general intelligence in an effective manner. The RIST consists of a verbal subtest ("Guess What"), which provides a measure of crystallized intelligence – the ability to use skills, knowledge, and experience, by relying on information stored in long-term memory (Jaeggi, Buschkuehl, Jonides, & Perrig, 2008). It also has a nonverbal subtest ("Odd Item Out") which provides a measure of fluid intelligence – the capacity to reason and solve novel problems, independent of any previous knowledge (Jaeggi, Buschkuehl, Jonides, & Perrig, 2008). The scores from these two subtests are summed and converted to a standard score, the RIST Index score. The RIST Index score provides an overall estimate of an individual's general intelligence and is also used as an indicator of risk for intellectual impairment (Reynolds & Kamphaus, 2002; Reynolds & Kamphaus, 2003). In addition to the RIST, we used another nonverbal, fluid intelligence subtest ("What´s Missing") from the RIAS; because participants may respond either verbally or nonverbally, the requirement for knowledge is reduced even further.

Measures of Verbal Fluency

Controlled Oral Word Association Test (COWAT) - The COWAT, also called the FAS test, measures verbal fluency. An adaptation of the test (Benton & Hamsher, 1978) was used in this study. In this task, the child was asked to name as many words as possible in a particular semantic category (e.g., animals, food), in one minute. After the semantic categories, the child was asked to name as many words as possible, starting with the sound "shh" (e.g., chair, chocolate, shoulder). The main dependent variable of this test was the amount of accurate responses in the semantic categories, and the amount of correct responses in the sound category.

Measures of Behaviour

Behavioural Assessment Scale for Children (Second Edition) (BASC-II) – The BASC-II applied a triangulation method for gathering information. By analyzing the child's behaviour from three perspectives—Self, Teacher, and Parent—it allows for a more complete and stable picture. The *BASC-II* provides the most comprehensive set of rating scales (Bledsoe, Semrud-Clikeman, & Pliszka, 2011). These scales measure areas important for DSM-IV classifications. In addition, the *BASC-II* is respected for its developmental sensitivity, and gives an extensive view of adaptive and maladaptive behaviour. The composite score domains presented in the *BASC-II* were evaluated using four rating forms which consist of Externalizing and ADHD Problems, Internalizing Problems, Social Withdrawal, and Adaptive Skills.

- Teacher Rating Scales (TRS). The TRS measured adaptive and problem behaviours in the preschool or school setting. Teachers completed forms at one of two age levels depending's on the child's age—preschool (ages 2 to 5), and child (ages 6 to 11) — in about 10-20 minutes. The forms, which contained 100-139 items, described specific behaviours that were rated on a four-point scale of frequency, ranging from "Never" to "Almost Always." Validity and response set indexes were also used to help judge the quality of the completed forms.
- Parent Rating Scales (PRS). The PRS measured both adaptive and problem behaviours in the community and home setting. Parents or caregivers completed forms at one of two age levels—preschool (ages 2 to 5), child (ages 6 to 11) —in about 10-20 minutes. The PRS contains 134-160 items and used a four-choice response format. Validity and response set indexes were also used to help judge the quality of completed forms.

- <u>Self-Report of Personality (SRP)</u>: The SRP– which was completed by children older than 7 years– provided insight into a child's thoughts and feelings.

Child Behaviour Questionnaire (CBQ) - The *CBQ* is a caregiver report measure that provides a highly differentiated assessment of temperament in children aged 3-7 years. It was developed to measure temperament as defined by relatively enduring biological make-up, reactivity (arousability of motor, affective, and sensory response systems), and self-regulation (processes that serve to modulate [increase or decrease] reactivity, including attentional focusing and inhibitory control). The CBQ assesses the following fifteen dimensions of temperament: activity level, anger/frustration, approach, attentional focusing, discomfort, falling reactivity and soothability, fear, high intensity pleasure, impulsivity, inhibitory control, low intensity pleasure, perceptual sensitivity, sadness, shyness, and smiling and laughter. Individual scale scores were combined to create factor scores for Surgency (Extraversion), Negative Affectivity, and Effortful Control. Internal consistency estimates range from .68 to .93, with a mean reliability estimate of .78 across the 15 scales.

The Temperament in Middle Childhood Questionnaire (TMCQ) - The TMCQ was designed to measure temperament in children aged 7 to 10 years. It assesses the following seventeen dimensions of temperament: Activity level, affiliation, anger/frustration, assertiveness/dominance, attentional focusing, discomfort, fantasy/openness, fear, high intensity pleasure, impulsivity, inhibitory control, low intensity pleasure, perceptual sensitivity, sadness, shyness, soothability/falling reactivity and activation control.

Interventionists

Our attention trainers included individuals with experience working with children, both healthy and diagnosed, and academic backgrounds in psychology. More specifically, our trainers were completing bachelor degrees in psychology or a related field at McGill University, Concordia or Université de Montréal. Staff training involved the review of materials, observation of experienced trainers, practice sessions with children, and evaluative feedback training. Meetings were held to provide feedback, group discussions, and supervision.

Group Design

All participants were assigned to one of three groups randomly as in Rueda et al. (2005).

Group 1 (Treatment Group): This group aimed to verify the training effect. The participants received attention training during the training period.

Group 2 (Passive-Control Group): This group aimed to control for training effect. To better attribute any training-related improvements, the study employed an active control group that also involved interaction with an attention trainer. The participants watched recorded videos of the training games and answered questions about the game posed by the computer. After the long term assessment, they were offered the attention training program.

Group 3 (Waitlist-Control Group): This group aimed to control for effect of the training and for the interaction between researcher and child. The participants received attention training after three months from the first assessment.

The following chart details the timeline followed by each of the three groups:

	Week 1	**Week 2-4**	**Week 5**	**Week 13** *(2 months following the end of the Attention Training program)*	**Week 17** *(1 month following the last assessment)*
Group 1: Treatment Group	1 hour pre-assessment session	10 sessions of intervention with an assigned attention trainer	1 hour post-assessment session	1 hour long-term assessment session	
Group 2: Passive-Control Group	1 hour pre-assessment session	10 sessions watching recorded videos of the training games, with an assigned attention trainer	1 hour post-assessment session	1 hour long-term assessment session	Intervention with assigned attention trainer offered to the child
Group 3: Waitlist-Control Group	1 hour pre-assessment session	No Intervention No Trainer	1 hour post-assessment session	1 hour long-term assessment session	Intervention with assigned attention trainer offered to the child

Table 2. Intervention Schedule

Attention Training Intervention

We used an adapted version of the 3-4 week protocol of the Rueda et al. (2005) study. These training games were programmed to train children on exercises related to the executive attention network. We modified their protocol by changing the duration of each session. We based our study design on the paradigm by Posner and colleagues (Rueda et al., 2005), and adapted it for use with children with disorders, in addition to children without disorders. This was influenced by pilot study results found by Golinsky in 2009. The adapted protocol in our study had more sessions in total (10 sessions), in which each last a shorter period of time (approximately 35 minutes). Overall, the 3-4 weeks following pre-assessment consisted of 10 sessions of training/control. A schedule for each week would consist of three sessions (i.e. 3 each week: one day of training, one day off and then two consecutive days of training).

The cognitive training intervention system used contains a range of cognitive exercises. The program included eighteen different age-appropriate exercises that were done on a rotating basis including visual tracking, reaction time, inhibition control, and working memory skills. The intervention materials were designed to train sustained, selective, alternating, and divided attention using visual and auditory stimuli. The visual stimuli included a number of games depicting animate versions of children and animals that could be distinguished by various features. The auditory stimuli included feedback on performance in the form of sounds (e.g., clapping). The tasks became progressively more difficult. After every level was reached, the game was changed. However, not all participants completed every game, because they progressed at different rates. Participants were given immediate evaluative feedback regarding their performance and trainers kept records of each participant's sessions, behaviour and progress.

We used a "motivational hierarchy" that was clearly explained to the child. They would begin as a Police Officer and ascend to other roles, such as Sergeant, Detective, Inspector and finally a Secret Agent. Each child received a "Secret Agent Academy ID" (*see Appendix C for picture of the Secret Agent Academy ID Card*) that visually described the level they could achieve. Each child was rewarded with a "secret prize" that reflected their position in the hierarchy. For instance, when they achieved the detective position, they received a magnifying glass and a certificate with their new title. In the intermediary time of being awarded a new role, the child would receive small stickers, in which an accumulation of four would allow them to attain the next role.

Before the training sessions began, trainers explained to each child that the aim of each session was to improve his/her training to get to the highest level in the hierarchy. We also showed the child the timeline of the day, which indicated when they would receive reinforcement (e.g., a break and stickers). The timeline indicated that after ten minutes of playing games, they would receive a five-minute break and a sticker. The stickers were given twice during one training session and were put on their "Secret Agent ID Card". The first sticker was given after ten minutes of attentive playing, during a five-minute break. During this break, trainers would tell the child that if they paid close attention in the second half of the training, they would receive their second sticker of the day.

To encourage the children to continue through the games, the attention trainers used evaluative feedback with general phrases of encouragement such as "You're so good at this game.", "Wow, you were so close, let's try that one again!", "It's okay, that one was just a little tricky, but I think you can do it this time! Let's try it again!", "We're almost done with this game! You're doing such a good job. Let's try just a couple more." Each exercise was meant to achieve a specific type of training, which tapped executive control and comprised a number of levels, with children progressing to the next level by making several correct responses in a row.

Anticipation exercises (training alerting attention) required the children to anticipate the movement of a duck across a pond by moving the cat to where they expect the duck would emerge. The *stimulus discrimination* (working memory) exercises consisted of a series of trials in which the child was required to remember a multiple-attribute item (e.g., different cartoon portraits) to pick out of an array. A *conflict resolution* (executive attention) set featured a number of S*troop-*

like exercises where children moved their joystick to pick out the larger of two arrays. Finally, there was an *inhibitory control exercise* (Go/No-Go task). Children were instructed to click as fast as possible when in one condition but withhold the response otherwise. All exercises became increasingly more difficult (Rueda & al., 2005).

To establish proficiency, the first exercises trained the children to track a cartoon cat on the computer screen by using a joystick. For example, in "Game 1- Be careful it's a trap!", children used a joystick to control an animated cat character (*see figure 2*). The goal was to move the cat to the grassy area at the side of the screen. In later levels, more of the grass was covered in mud, which was filled with traps. The cat had to search for clues in the grass and avoid getting caught. Successfully completing a trial by moving the cat to the grass resulted in the cat grinning and dancing. Moving the cat into the mud, or not moving the cat to the side within the time limit, did not complete the trial successfully and resulted in a frowning cat. Trainers gave participants the following instructions: "The mud is filled with traps. Move Agent Cat as fast as you can to the grass." If children ran out of time, trainers would encourage them by saying "Oops! Agent Cat ran out of time. Let's try again- and this time, try to move Agent Cat to the grass as fast as you can!" If children were headed toward the mud, trainers would say "Uh-oh, you're almost going into the mud! Make sure you stop! What can we do to get to the grass?"

Figure 2. Screenshot of Game 1- Be careful it's a trap!

Results

Since this thesis work is embedded in a larger project that is still in session, data collection for the control groups is still ongoing. We could compare our experimental group (*group 1*) to the waitlist control group (*group 3*), which currently has more participants than the passive-control group (*group 2*). The latter was added as a supplementary condition, in order to control for the effects of the interventionists in our study. Data collection for these groups is more difficult than the experimental group, as parents and schools at times feel that it is unethical for us to offer a seemingly advantageous intervention to one group of children and not the other, despite the offering of the intervention upon completion of the round. Consequently, data collection for the control groups is slower. Nonetheless, it is an ongoing process and we intend to report on the complete findings within the next few months.

As a result, the following analyses only include participants in the experimental group. Analyses examine differences in scores between the pre-assessment and post-assessment, as well as potential age, diagnosis and gender influences. We hypothesized that children's scores would increase on all measures after receiving attention training sessions; that girls and boys would improve similarly; and we believed that children with disorders would show bigger improvements in behaviour in relation to children without disorders. While all kids were eligible for the RIST (N = 103), many children were included after the addition of the BSRT, COWAT (N = 36) and some were too young for the D2, the BDS, which reduced our sample for those tests (N = 25). We also analyzed behavioural scales (BASC-II, CBQ and TMQ) based on self, parent and teacher reports.

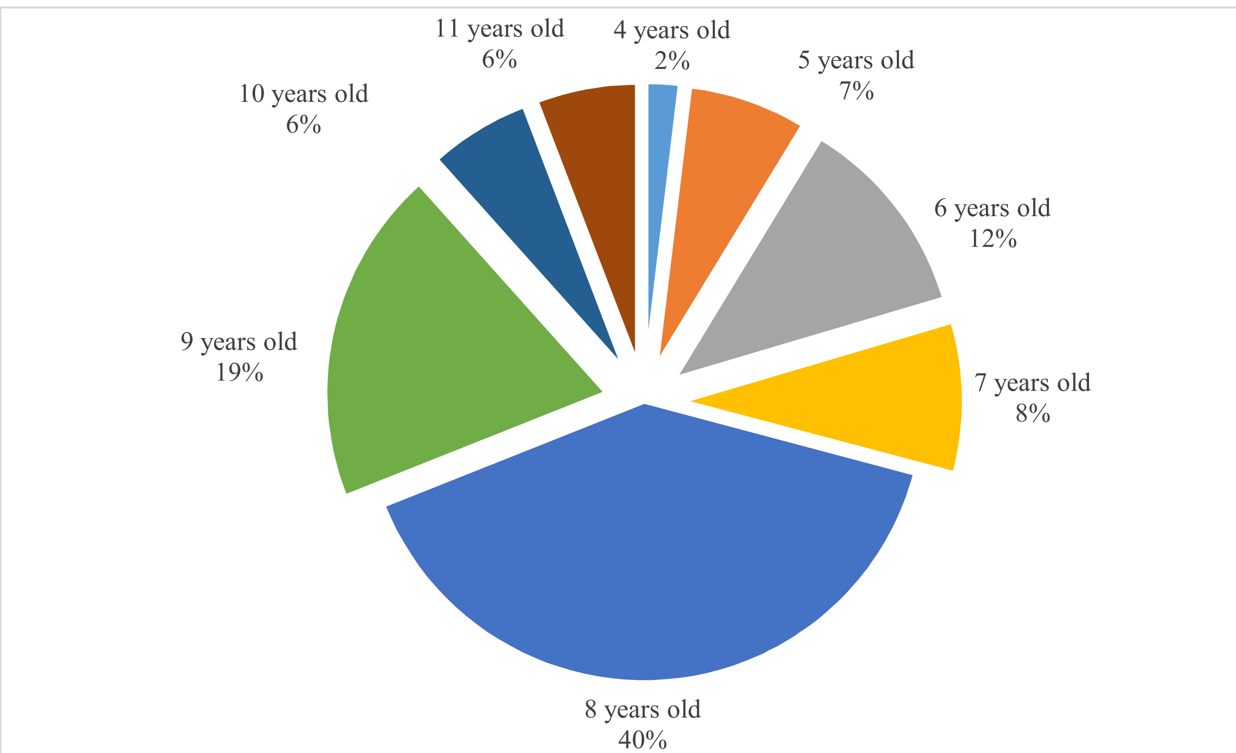

Figure 3. Age Frequencies of Participants

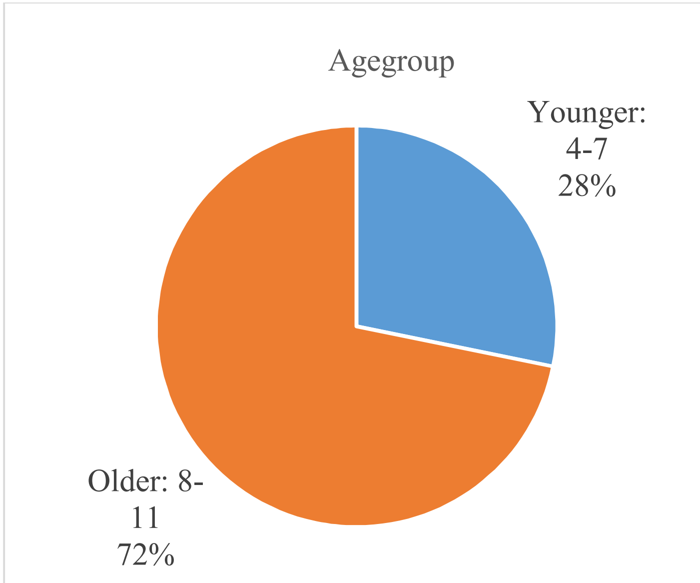

Figure 4. Agegroup Frequencies of Participants

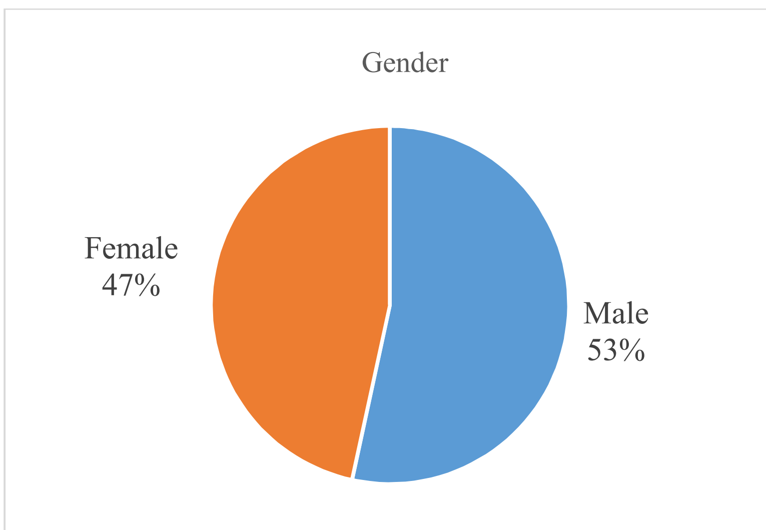

Figure 5. Gender Frequencies of Participants

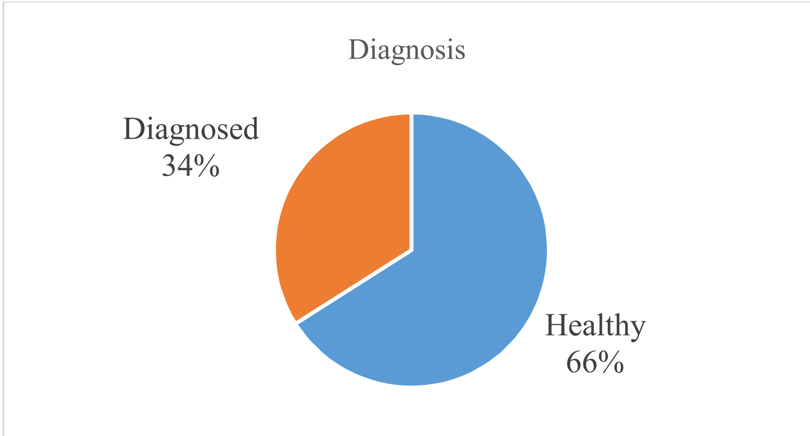

Figure 6. Diagnosis Frequencies of Participants

Measure of Attention

D2 Test of Concentrated Attention

We conducted a mixed within and between subjects ANOVA to compare scores on the D2 for the pre-, post- assessments and across genders. Refer to Table 3 for means and standard deviations. The ANOVA conducted on the *"D2 Test of Concentrated Attention"* revealed a significant main effect of Time, F (1,21) = 17.420, ($p<.01$), partial eta squared =.453 with an observed power = .978.

Time	Mean	Standard Error	95% Confidence Interval	
			Lower Bound	**Upper Bound**
1	99.049	1.880	95.139	102.960
2	107.288	2.180	102.754	111.822

Table 3. Means and Standard Deviations for the D2 Test of Concentrated Attention.

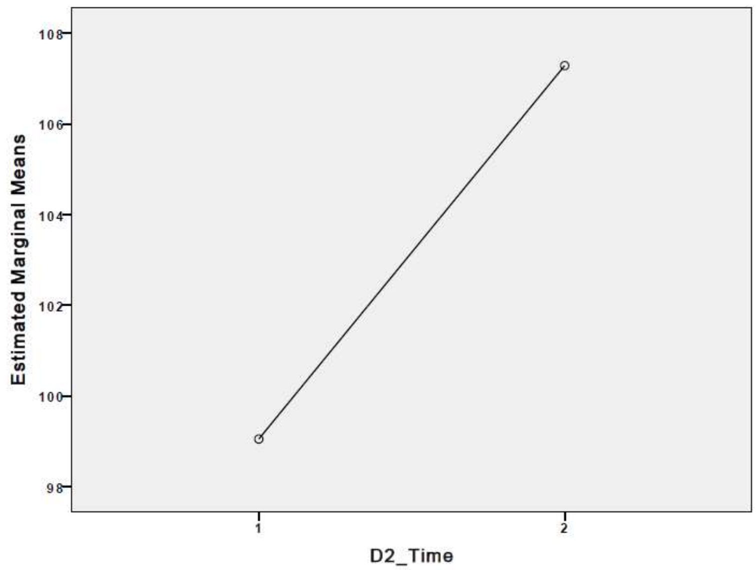

Figure 7. Main effect of Time in D2 Test of Concentrated Attention.

Measure of Verbal Fluency

<u>Controlled Oral Word Association Task (COWAT)</u>

We conducted a mixed within between subjects ANOVA to compare scores on the COWAT on pre- and post- assessments and across genders. Refer to Table 4 for means and standard deviations. In this analysis, in which we controlled for age, we only observed a 3-way interaction between Time, Agegroup, and Sex, $F(1,31) = 7.697$, ($p<.05$), partial eta squared = .199, and an observed power = .767. These results demonstrated that older females benefitted more from the intervention than the other groups.

Agegroup	Sex	Time	Mean	Standard Error	95% Confidence Interval	
					Lower Bound	Upper Bound
Younger kids (4-7 years old)	Male	1	21.345[a]	3.675	13.849	28.841
		2	22.583[a]	4.166	14.087	31.079
	Female	1	17.207[a]	3.837	9.383	25.032
		2	24.770[a]	4.348	15.902	33.638
Older kids (8-11 years old)	Male	1	28.689[a]	2.575	23.437	33.942
		2	34.747[a]	2.919	28.794	40.701
	Female	1	28.968[a]	2.560	23.746	34.190
		2	31.772[a]	2.902	25.853	37.691

Table 4. COWAT Means and SDs (3-way interaction: Agegroup * Sex* Time).

a. Covariates appearing in the model are evaluated at the following values: AGE= 7.67.

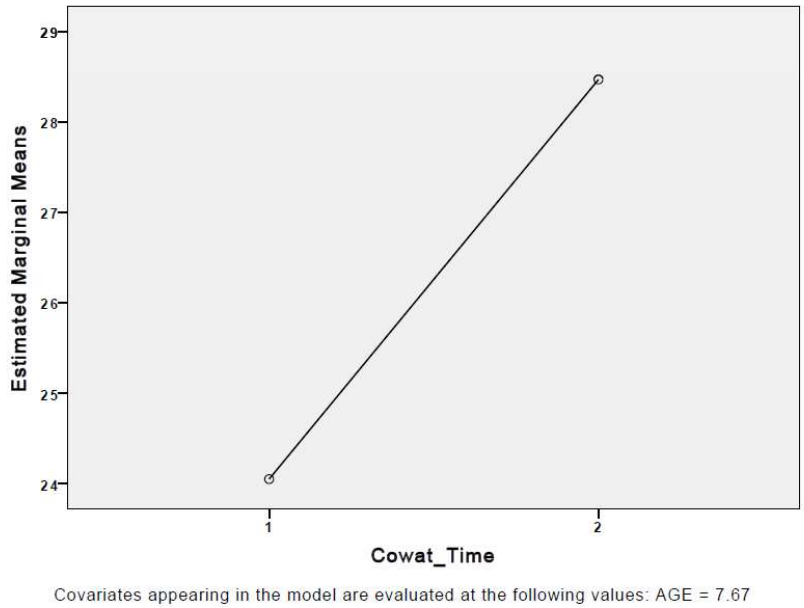

Figure 8. Main Effect of Time in COWAT.

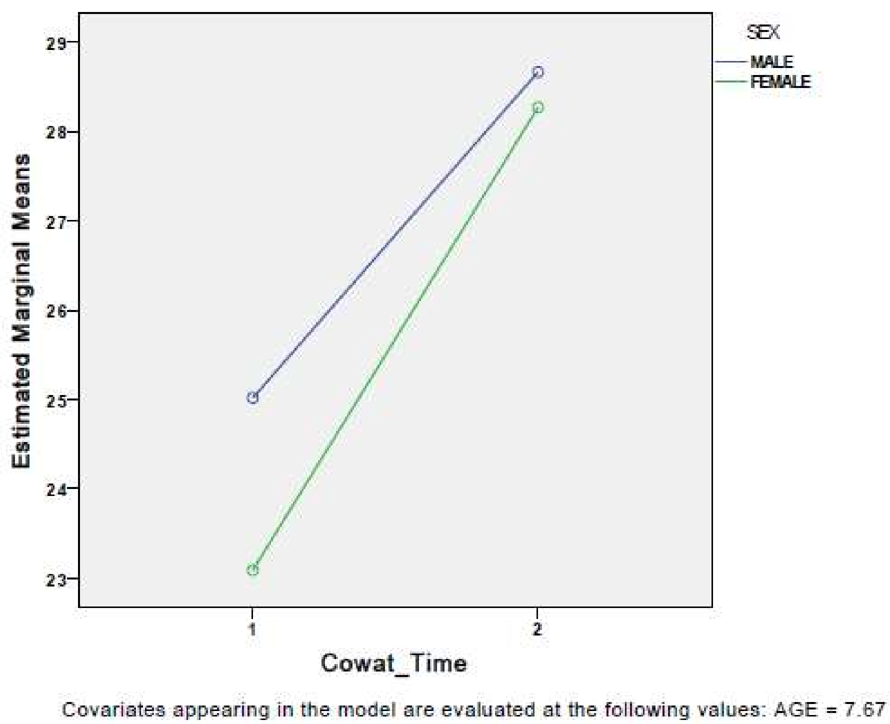

Figure 9. Time*Sex Interaction in COWAT.

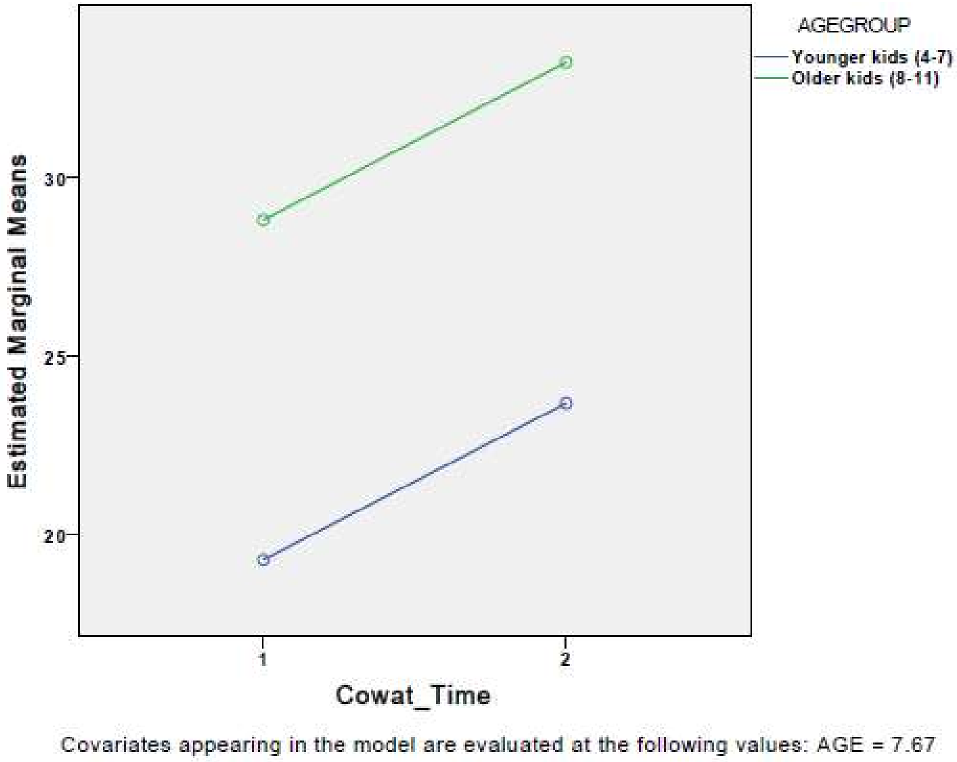

Figure 10. Time*Agegroup Interaction in COWAT

Measures of Working Memory

<u>Bushcke Selective Reminding Task (BSRT)</u>

We conducted a mixed within between subjects ANOVA to compare scores on the BSRT across pre-, and post- assessments. The analyses conducted on the BSRT revealed no significant effects. Refer to Table 5 for means and standard deviations. In this analysis, there was no significant effect of Time, F (1,31) = .092, p= .763, partial eta squared= .003 and an observed power= .060.

Time	Mean	Standard Error	95% Confidence Interval	
			Lower Bound	**Upper Bound**
1	37.217[a]	1.094	34.986	39.448
2	39.255[a]	.749	37.727	40.782

Table 5. Means and Standard Deviations for the BSRT.

a. Covariates appearing in the model are evaluated at the following values: AGE = 7.61.

Backward Digit Span (BDS)

We conducted a mixed within between subjects ANOVA to compare scores on the BDS across pre-, and post- assessments and across genders. Refer to Table 6 for means and standard deviations. In this analysis, in which we controlled for age, we observed a significant main effect of Time, $F(1,23) = 6.755$, ($p<.05$), partial eta squared = .227 with an observed power= .702. Participants' score significantly increased over time.

Time	Mean	Standard Error	95% Confidence Interval	
			Lower Bound	**Upper Bound**
1	10.205	.659	8.841	11.569
2	11.869	.689	10.443	13.294

Table 6. Means and Standard Deviations for the BDS.

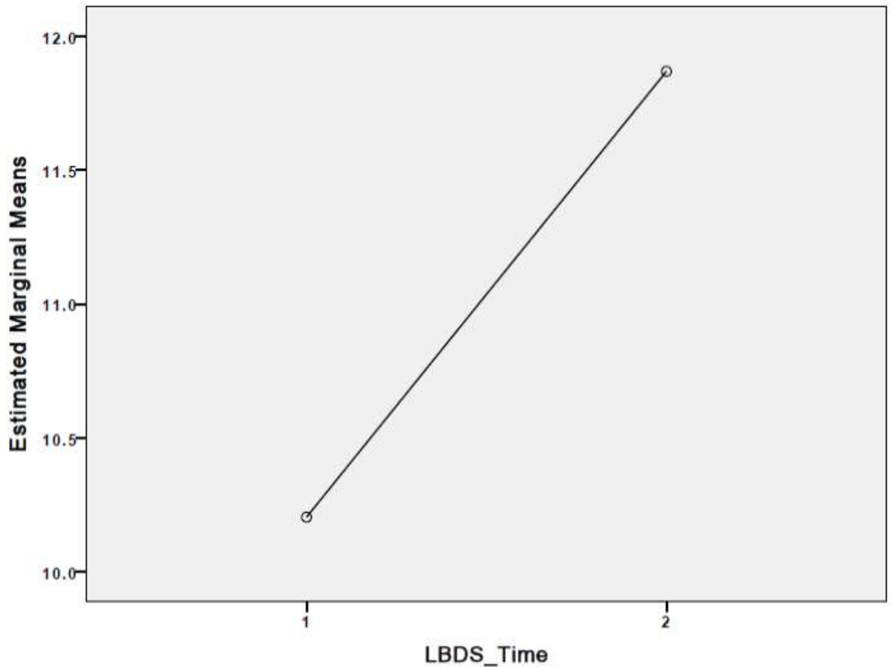

Figure 11. Main Effect of Time in BDS.

Measures of Intelligence

RAIS/RIST

We converted all the raw scores obtained to standardized T scores. We began by analyzing the verbal subtest "*Guess What*". Refer to Table 7 for means and standard deviations. This ANOVA revealed a significant main effect of Time, F(1,81) = 5.199 (p<.05), partial eta squared = .060 with an observed power= .615.

Time	Mean	Standard Error	95% Confidence Interval	
			Lower Bound	**Upper Bound**
1	52.960	1.581	49.814	56.106
2	55.873	1.427	53.034	58.711

Table 7. Means and Standard Deviations of "Guess What" subtest.

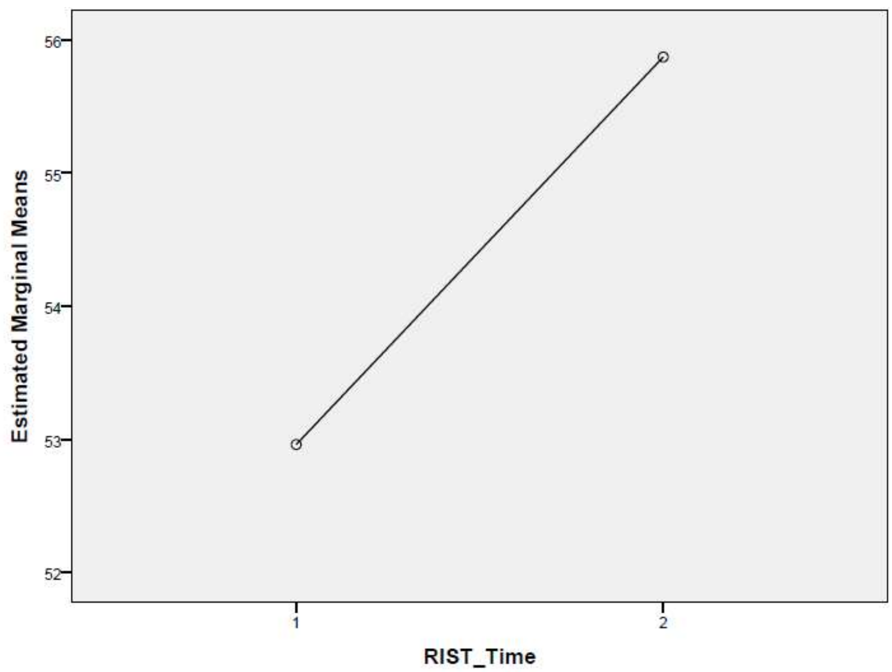

Figure 12. Main Effect of Time in RIST/RAIS.

We proceeded and analyzed the non-verbal subtests of the RIST, "*Odd-Item Odd*" and "*What's Missing*". These analyses revealed significant main effects of Time for both subtests. Refer to Tables 8-9 for means and standard deviations. *What's Missing:* $F(1,84) = 47.678$ ($p<.001$), partial eta squared = .362 with an observed power= 1.000. *Odd-Item Out*: $F(1,86) = 10.404$ ($p<.05$), partial eta squared = .108 with an observed power= .891.

Time	Mean	Standard Error	95% Confidence Interval	
			Lower Bound	**Upper Bound**
1	45.828	1.523	42.798	48.857
2	54.258	1.373	51.529	56.988

Table 8. Means and Standard Deviations of "What's Missing" subtest.

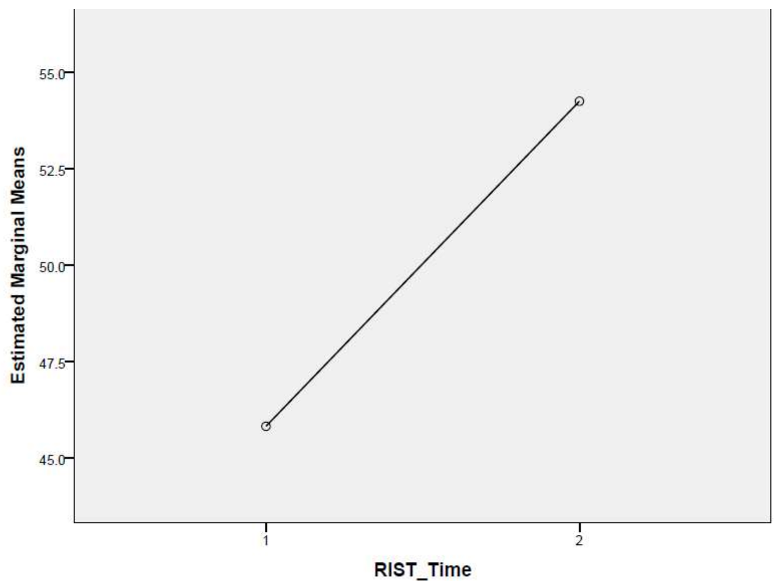

Figure 13. Main Effect of Time in WHM.

Time	Mean	Standard Error	95% Confidence Interval	
			Lower Bound	**Upper Bound**
1	52.406	1.408	49.606	55.206
2	57.387	.932	55.534	59.239

Table 9. Means and Standard Deviations of “Odd-Item Out” subtest.

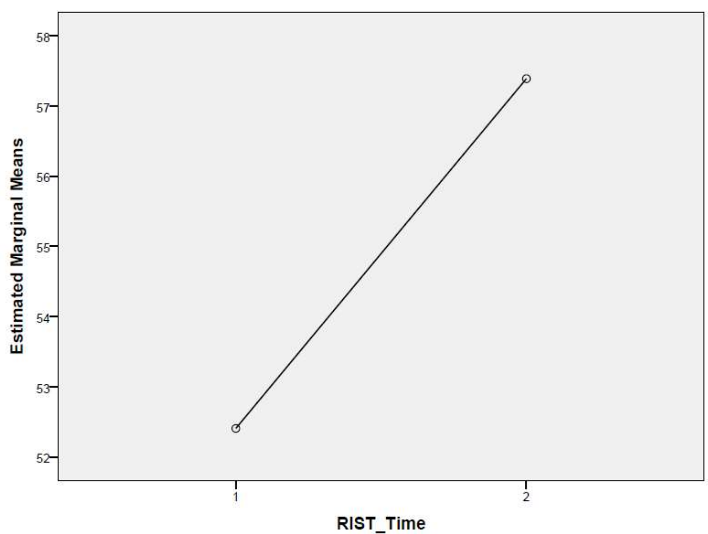

Figure 14. Main Effect of Time in OIO.

Finally, we analyzed the RIST index. Refer to Table 10 for means and standard deviations. This ANOVA yielded a significant main effect of Time, $F(1,81) = 13.145$ ($p<.001$), partial eta squared = .140 with an observed power= .948.

Time	Mean	Standard Error	95% Confidence Interval	
			Lower Bound	**Upper Bound**
1	106.275	1.995	102.305	110.245
2	113.010	1.774	109.480	116.540

Table 10. Means and Standard Deviations of the RIST Index.

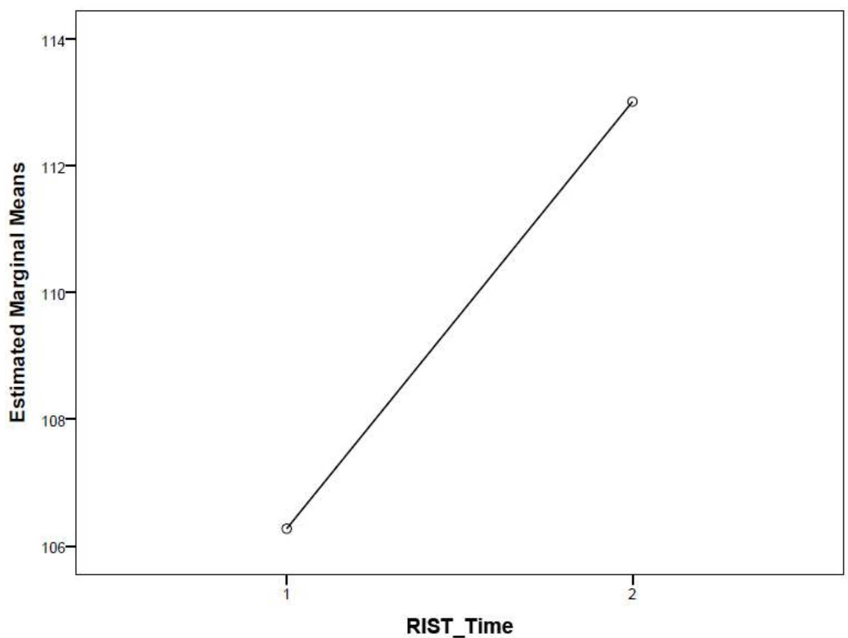

Figure 15. Main Effect of Time in RIST Index.

Measures of Behaviour

BASC-II

All the raw scores we obtained on the BASC-II questionnaires were converted to standardized T scores. Subsequently, we compared these scores to general norms based on a large sample representative of the general population of children in the United States, in relation to race, ethnicity, region, parental education, and clinical or special-education classification (Reynolds & Kamphaus, 2004).

Self-Report (SRP)

For the self-report, the subscales we analyzed include Depression; Locus of Control; Hyperactivity; and Anxiety. We observed a main effect of Time in the Depression subscale, $F(1,39) = 5.324$ ($p<.05$), partial eta squared = .120 with an observed power= .614. Refer to Table 11 for means and standard deviations. The ANOVAs for the Hyperactivity and Anxiety subscales did not reveal significant effects.

Time	Mean	Standard Error	95% Confidence Interval	
			Lower Bound	**Upper Bound**
1	47.430	.963	45.483	49.378
2	46.053	.852	44.331	47.776

Table 11. Means and Standard Deviations of the Depression subscale in the BASC-II: SRP.

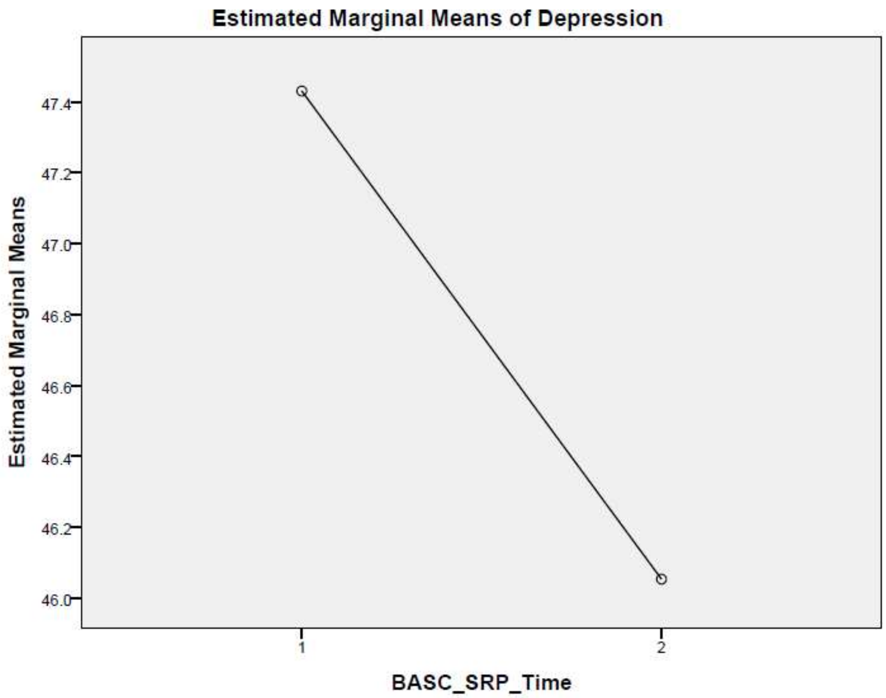

Figure 17. Plot of Depression subscale (BASC-II: SRP)

Parent Rating Scale (PRS)

For the parent rating scale, the subscales we analyzed include Depression; Anger; Hyperactivity; and Anxiety. The ANOVAs for the Hyperactivity and Anxiety subscales did not reveal significant effects. We observed a main effect of Time in the Depression subscale, $F(1,54) = 10.429$ ($p<.05$), partial eta squared = .162 with an observed power= .887; a significant Time by Diagnosis two-way interaction in the Depression subscale, $F(1,54) = 4.637$ ($p<.05$), partial eta squared = .079 with an observed power= .562; and a significant Time by Sex by Agegroup three-way interaction in the Depression subscale, $F(1,54) = 7.241$ ($p<.01$), partial eta squared = .118 with an observed power= .753. These results demonstrated that significant decreases in all participants, but also showed that children with an impulse control diagnosis benefitted more from the intervention than the other groups. The results also suggest that younger females improved more, when compared to the remaining subjects. Refer to Table 12-14 for means and standard deviations.

Time	Mean	Standard Error	95% Confidence Interval	
			Lower Bound	**Upper Bound**
1	52.763	1.423	49.910	55.616
2	48.783	1.176	46.426	51.140

Table 12. Means and Standard Deviations of the Depression subscale in the BASC-II: PRS.

Diagnosis	Time	Mean	Standard Error	95% Confidence Interval	
				Lower Bound	**Upper Bound**
Healthy	**1**	47.976	1.636	44.695	51.256
	2	46.650	1.352	43.939	49.361
Diagnosed	**1**	57.550	2.328	52.882	62.218
	2	50.917	1.924	47.060	54.774

Table 13. Means and Standard Deviations of the Depression subscale in the BASC-II: PRS.

Time*Diagnosis Interaction

Sex	Agegroup	Time	Mean	Standard Error	95% Confidence Interval	
					Lower Bound	**Upper Bound**
Male	Younger children (4-7)	**1**	51.083	2.603	45.864	56.302
		2	50.667	2.151	46.354	54.979
	Older children (8-11)	**1**	52.433	1.746	48.932	55.934
		2	48.292	1.443	45.399	51.184
Female	Younger children (4-7)	**1**	54.650	3.772	47.087	62.213
		2	44.200	3.117	37.951	50.449
	Older children (8-11)	**1**	52.885	2.888	47.095	58.674
		2	51.974	2.386	47.190	56.758

Table 14. Means and Standard Deviations of the Depression subscale in the BASC-II: PRS.

Time*Sex*Agegroup Interaction

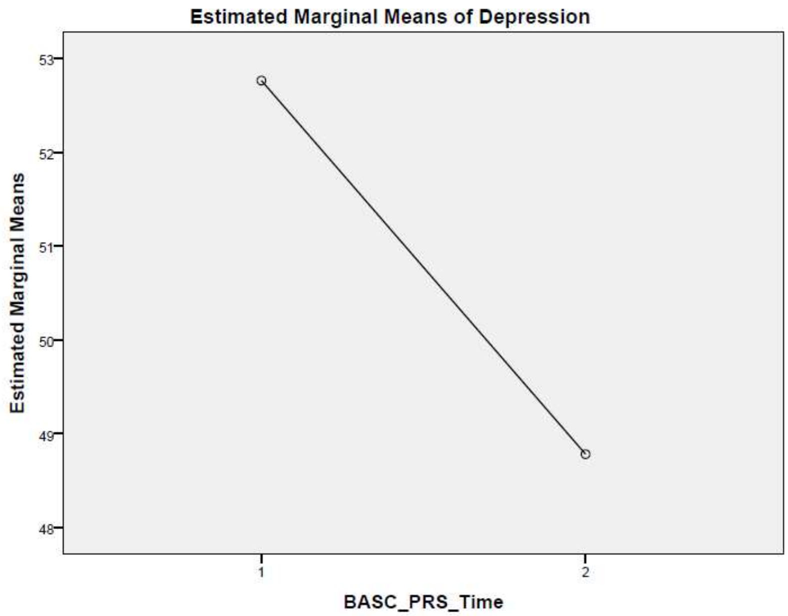

Figure 18. Plot of Depression subscale (BASC-II: PRS)

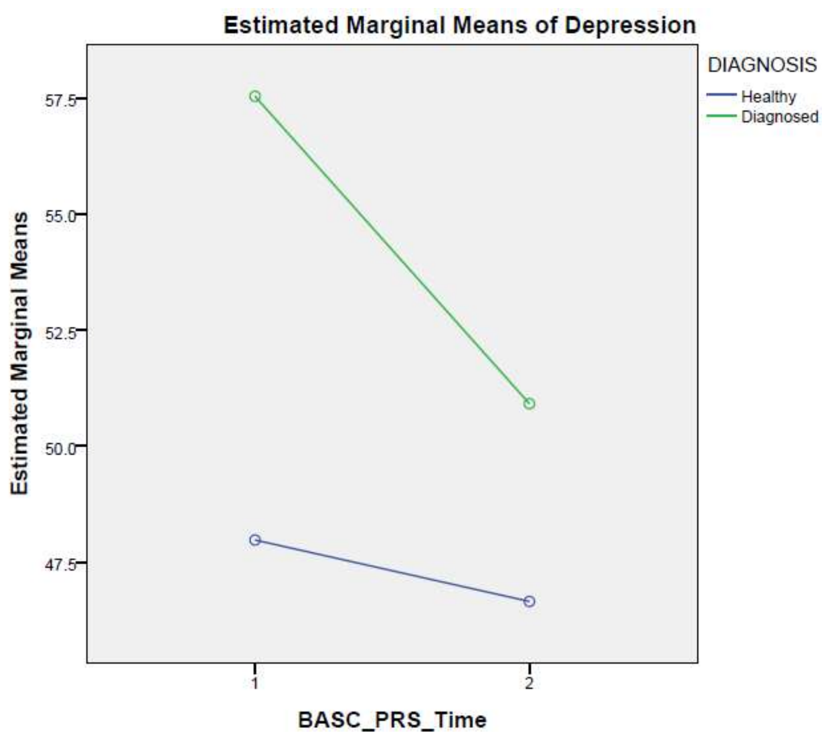

Figure 19. Plot of Depression subscale (BASC-II: PRS). Time*Diagnosis Interaction

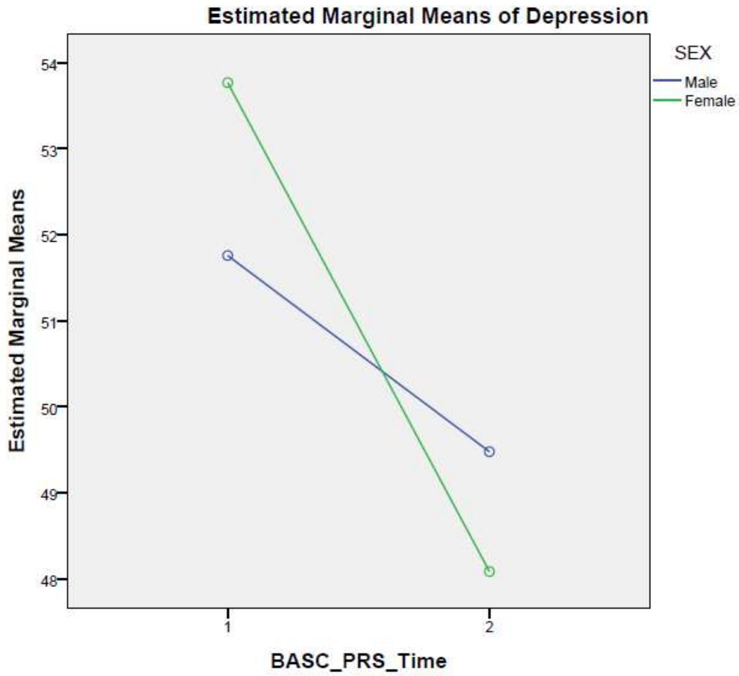

Figure 20. Plot of Depression subscale (BASC-II: PRS). Time*Sex Interaction

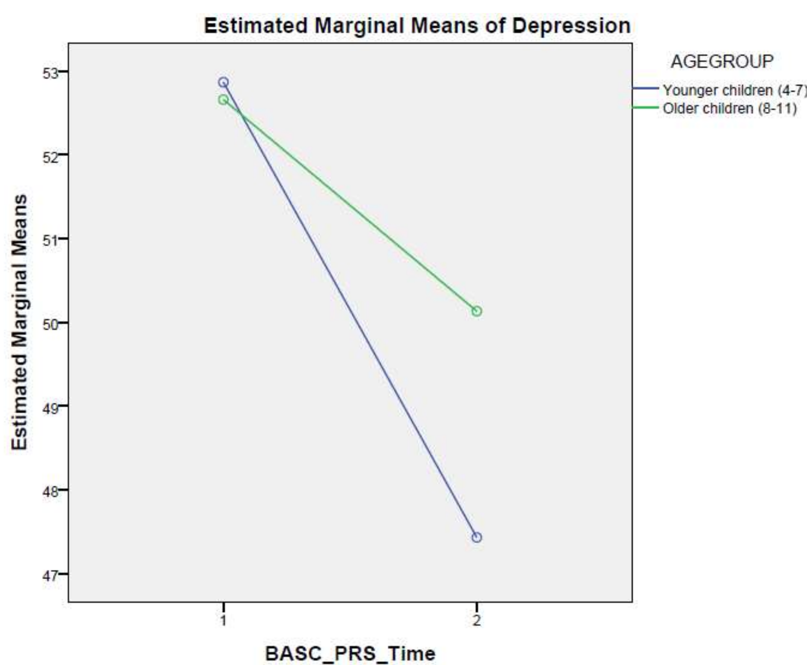

Figure 21. Plot of Depression subscale (BASC-II: PRS). Time*Agegroup Interaction

When it comes to the Anger subscale, the ANOVAs revealed a significant main effect of Time, $F(1,55) = 6.054$ ($p<.05$), partial eta squared = .099 with an observed power= .676, and a significant four-way interaction of Time, Sex, Agegroup and Diagnosis, $F(1,55) = 6.448$ ($p<.05$), partial eta squared = .105 with an observed power= .704. These results demonstrate that younger diagnosed males benefitted more from the intervention, when compared to the other subjects. Refer to Tables 15-16 for means and standard deviations.

Time	Mean	Standard Error	95% Confidence Interval	
			Lower Bound	**Upper Bound**
1	53.321	1.644	50.023	56.620
2	51.779	1.365	49.041	54.518

Table 15. Means and Standard Deviations of the Anger subscale in the BASC-II: PRS.

Sex	Agegroup	Diagnosis	Time	Mean	Standard Error	95% Confidence Interval	
						Lower Bound	**Upper Bound**
Male	Younger children (4-7)	Healthy	**1**	50.333	3.712	42.888	57.778
			2	51.000	3.082	44.819	57.181
		Diagnosed	**1**	59.167	3.712	51.722	66.612
			2	56.500	3.082	50.319	62.681
	Older children (8-11)	Healthy	**1**	51.667	2.625	46.402	56.931
			2	48.750	2.179	44.379	53.121
		Diagnosed	**1**	55.200	2.348	50.491	59.909
			2	52.000	1.949	48.091	55.909
Female	Younger children (4-7)	Healthy	**1**	49.000	4.066	40.845	57.155
			2	47.600	3.376	40.829	54.371
		Diagnosed	**1**	61.000	9.092	42.764	79.236
			2	55.000	7.549	39.859	70.141
	Older children (8-11)	Healthy	**1**	49.538	2.522	44.481	54.596
			2	48.385	2.094	44.185	52.584
		Diagnosed	**1**	50.667	5.249	40.138	61.195
			2	55.000	4.358	46.259	63.741

Table 16. Means and Standard Deviations of the Anger subscale in the BASC-II: PRS.

Time*Sex*Agegroup*Diagnosis Interaction

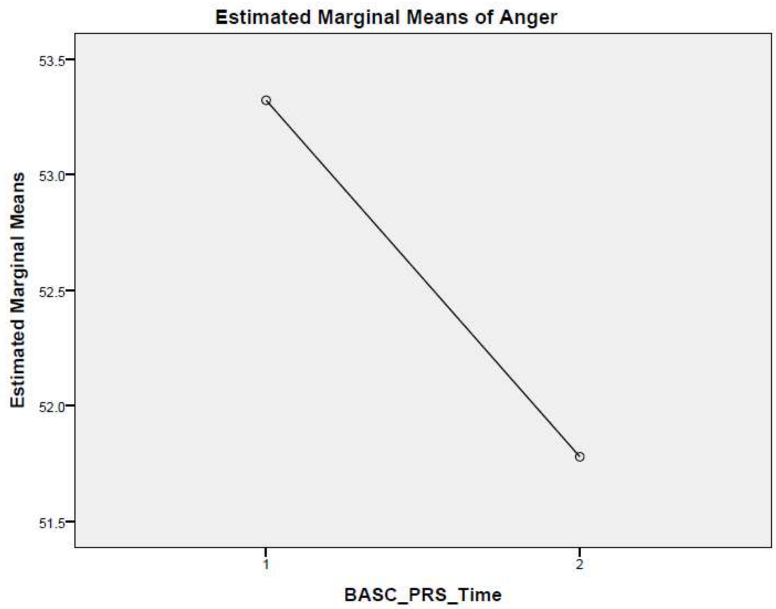

Figure 22. Plot of Anger subscale (BASC-II: PRS)

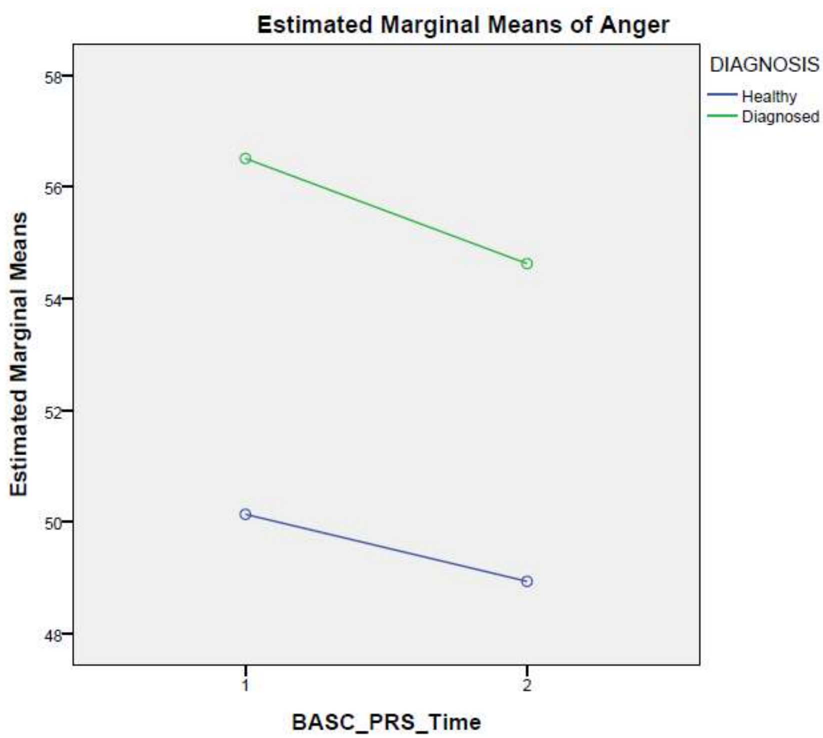

Figure 23. Plot of Anger subscale (BASC-II: PRS). Time*Diagnosis Interaction

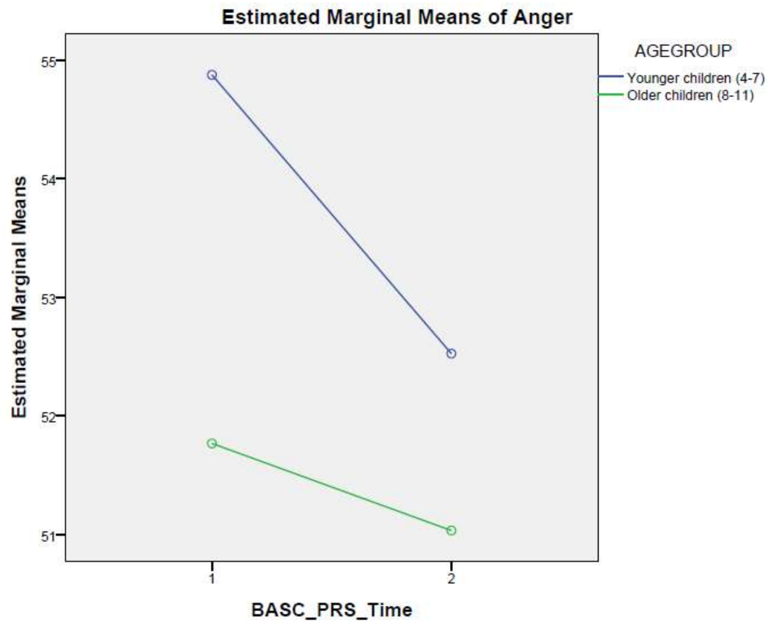

Figure 24. Plot of Anger subscale (BASC-II: PRS). Time*Agegroup Interaction

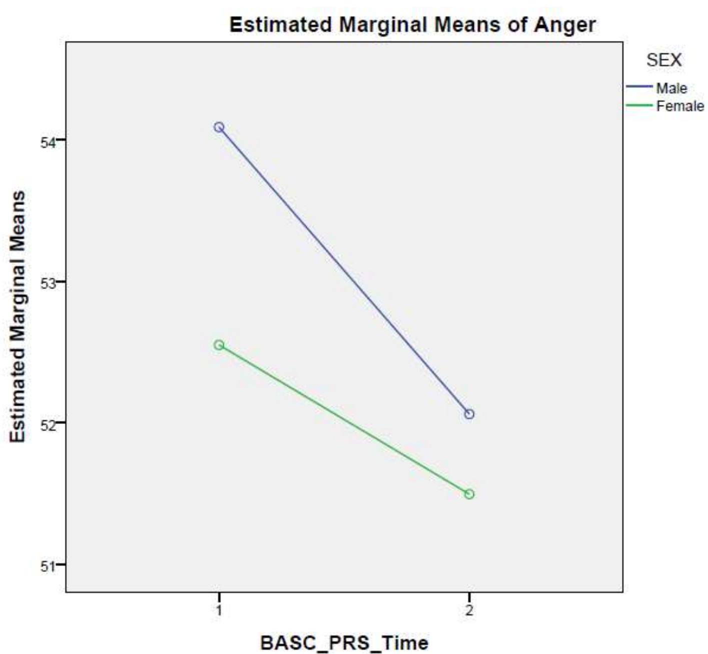

Figure 25. Plot of Anger subscale (BASC-II: PRS). Time*Sex Interaction

Teacher Rating Scale (TRS)

For the teacher rating scale, the subscales we analyzed include Depression; Hyperactivity; Aggression; and Anxiety. The ANOVAs for the Depression, Aggression, and Anxiety subscales did not reveal significant effects. We observed a significant three-way interaction of Time, Sex, and Diagnosis in the Hyperactivity subscale, $F(1,54) = 4.661$ ($p<.05$), partial eta squared = .107 with an observed power=.558. Refer to Table 17 for means and standard deviations.

Sex	Diagnosis	Time	Mean	Standard Error	95% Confidence Interval	
					Lower Bound	**Upper Bound**
Male	Healthy	**1**	55.958	2.634	50.631	61.286
		2	53.908	2.248	49.362	58.454
	Diagnosed	**1**	51.667[a]	4.040	43.495	59.839
		2	55.833[a]	3.448	48.860	62.807
Female	Healthy	**1**	51.731	3.169	45.320	58.141
		2	50.551	2.704	45.081	56.022
	Diagnosed	**1**	48.000	5.345	37.190	58.810
		2	46.667	4.561	37.442	55.892

a. Based on modified population marginal mean.

Table 17. Means and Standard Deviations of the Depression subscale in the BASC-II: TRS. Time*Sex*Diagnosis Interaction

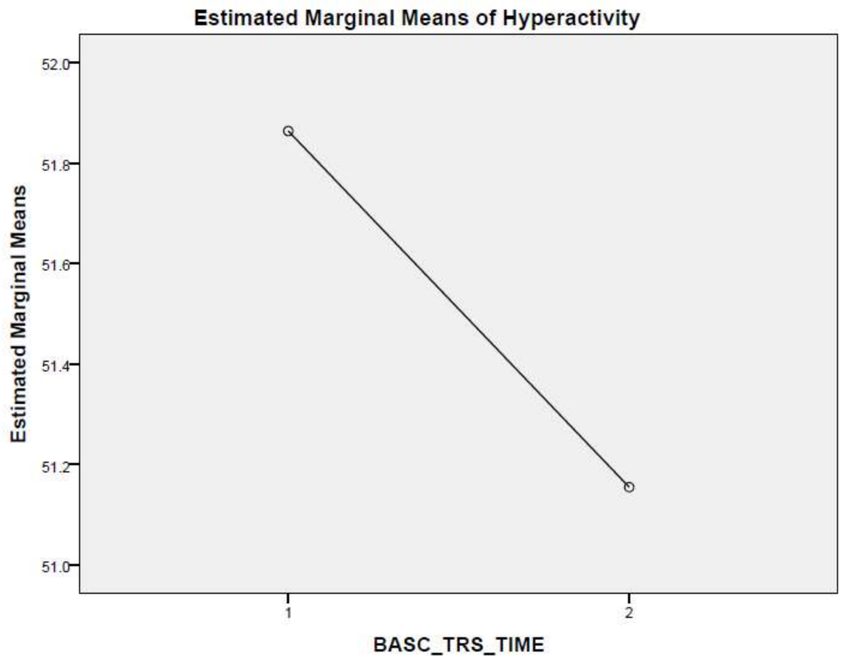

Figure 26. Plot of Hyperactivity subscale (BASC-II: TRS).

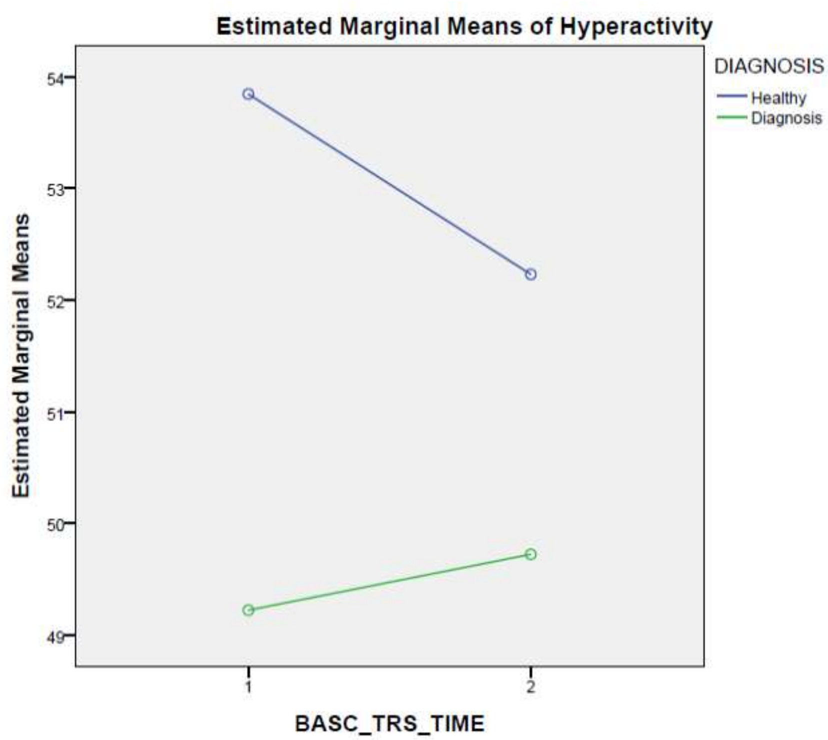

Figure 27. Plot of Hyperactivity subscale (BASC-II: TRS). Time*Diagnosis interaction

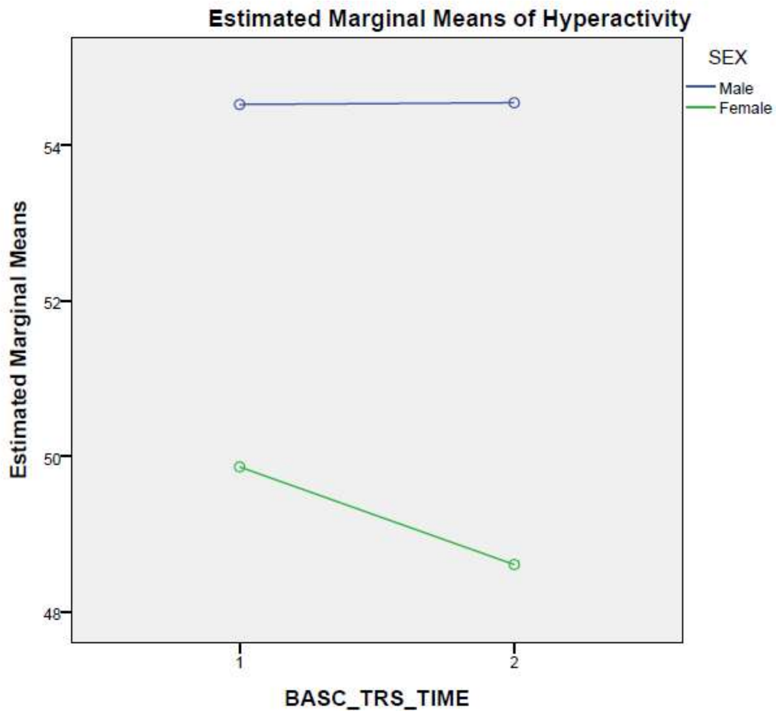

Figure 28. Plot of Hyperactivity subscale (BASC-II: TRS). Time*Sex interaction.

CBQ/TMQ

We compared the data obtained from the CBQ and TMCQ and we normalized all scores. In our statistical analyses for the parent and teacher questionnaires, we considered the following subscales: Impulsivity, Shyness, Anger/Frustration, Inhibition Control and Negative Affect. In the parent questionnaires, the ANOVAs did not reveal significant effects. However, in the teacher questionnaires, we observed a significant four-way interaction of Time, Sex, Diagnosis and Agegroup in the Impulsivity subscale, $F(1,31) = 5.859$ ($p<.05$), partial eta squared = .159 with an observed power=.650. These results suggest that in relation to impulsivity, younger diagnosed females benefitted more from the intervention. Refer to Table 18 for means and standard deviations.

Sex	Agegroup	Diagnosis	Time	Mean	Standard Error	95% Confidence Interval	
						Lower Bound	**Upper Bound**
Male	Younger children (4-7)	Healthy	**1**	3.150	.292	2.555	3.745
			2	3.214	.271	2.662	3.766
		Diagnosed	**1**	2.424	.257	1.899	2.949
			2	2.568	.239	2.082	3.055
	Older children (8-11)	Healthy	**1**	2.965	.386	2.178	3.752
			2	3.429	.358	2.700	4.159
		Diagnosed	**1**	2.846	.446	1.937	3.755
			2	2.897	.413	2.054	3.740
Female	Younger children (4-7)	Healthy	**1**	3.333	.546	2.220	4.447
			2	3.417	.506	2.384	4.449
		Diagnosed	**1**	2.568	.257	2.044	3.093
			2	2.352	.239	1.866	2.839
	Older children (8-11)	Healthy	**1**	2.000	.772	.426	3.574
			2	1.077	.716	-.383	2.537
		Diagnosed	**1**	2.982	.386	2.195	3.770
			2	2.865	.358	2.135	3.595

Table 18. Means and Standard Deviations of the Impulsivity subscale in the CBQ/TMQ: Teachers. Time*Sex*Diagnosis*Agegroup Interaction

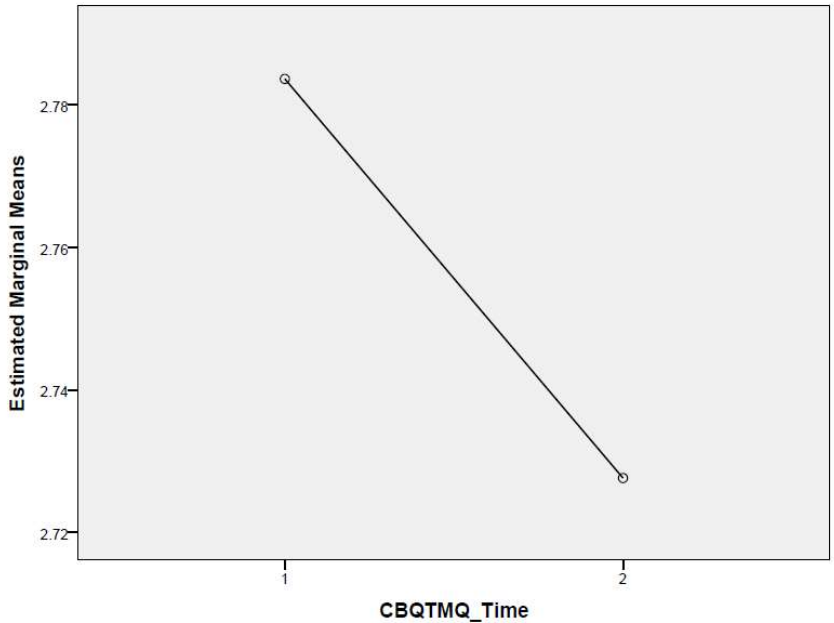

Figure 29. Plot of Impulsivity subscale (CBQ/TMQ).

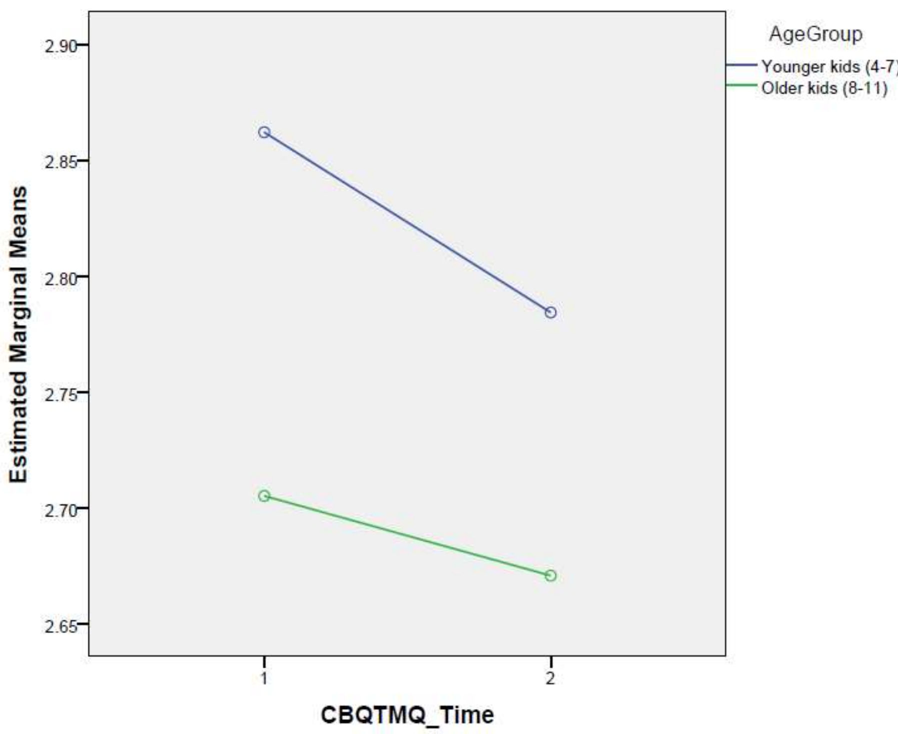

Figure 30. Plot of Impulsivity subscale (CBQ/TMQ). Time*Agegroup Interaction.

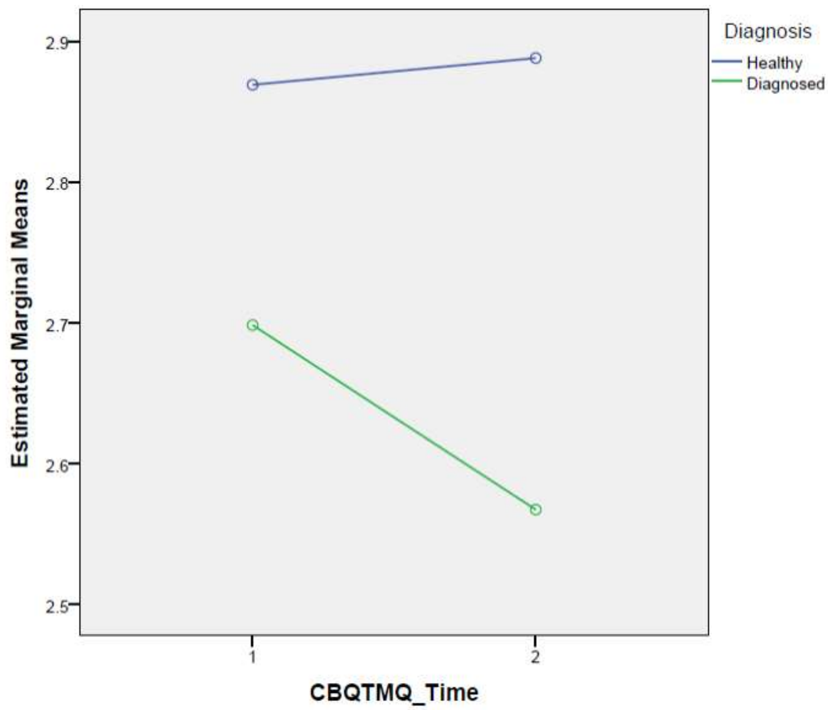

Figure 31. Plot of Impulsivity subscale (CBQ/TMQ). Time*Diagnosis Interaction.

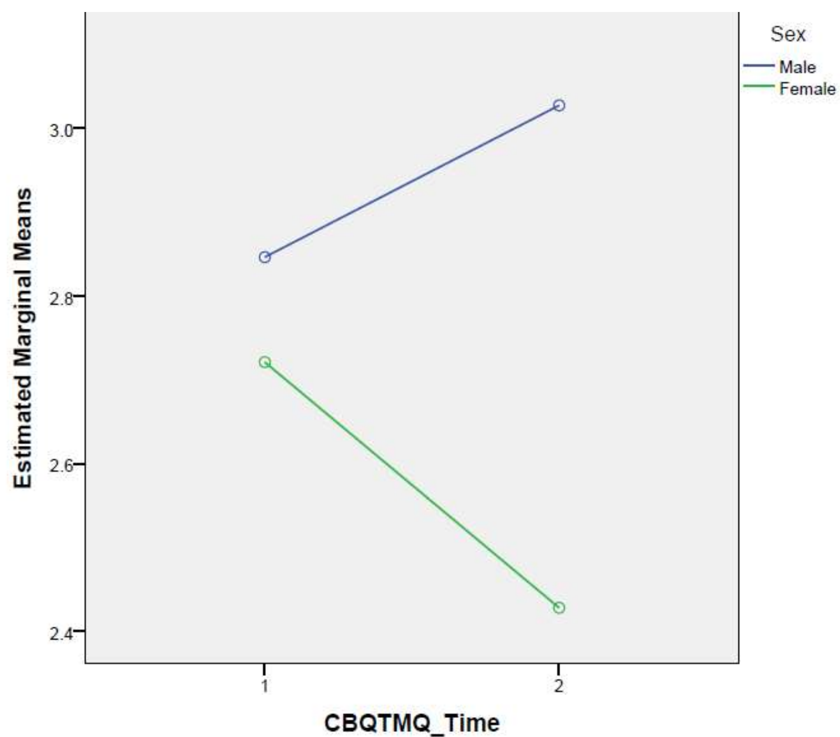

Figure 32. Plot of Impulsivity subscale (CBQ/TMQ). Time*Sex Interaction.

Discussion

Here, we report findings from a controlled computerized attention training study by assessing its effects on verbal and nonverbal memory, attention and global functioning in healthy children and children with behavioural disorders, such as attention-deficit hyperactivity disorder, oppositional defiant disorder and conduct disorder.

The results suggest that attention training can affect these functions as demonstrated in the neuropsychological assessments conducted before and after the completion of the training program. Overall, participants significantly improved on measures of attention, verbal fluency, intelligence, working memory and some aspects of behaviour. Children, regardless of diagnosis, age and gender improved on general measures of intelligence, both verbal and nonverbal; on a measure of concentrated attention; and on one measure of working memory. However, when it comes to verbal fluency, only older females responded better to the program, as evidenced by their improvement on this measure. In measures of behaviour, children old enough to complete self-reports reported significantly lower levels of depression following the intervention; however, we did not observe meaningfully decreased levels of hyperactivity and anxiety.

Our data obtained from parent questionnaires (BASC-II) suggested that the attention training intervention offered some benefits to depression and anger. Parents reported significant decreases in depression and anger in all children. When it comes to subjective parent reports on anger, however, younger diagnosed males seem to have benefited more than the other participants. Teachers also observed a significant decrease in hyperactivity in healthy female participants, in addition to a meaningful decrease in impulsivity in younger diagnosed females, as evidence in BASC-II and CBQ/TMQ reports. The findings demonstrate that the attention training intervention, the motivational component, and the incentives led to subjective improvements in addition to the objective improvements previously discussed.

In comparable studies of attention training, the literature demonstrates that the effects of the computerized interventions are sustainable up to a year following their completion (Shinaver III, Entwistle & Söderqvist, 2014). In our study, we also collected long-term assessments that we will analyze and report once we complete the study.

Limitations

The findings of this study may raise many significant issues, but there are some possible limitations of the research. To begin with, the lack of comparison between the experimental and control groups does not allow us to know specifically where the effect is coming from. Additionally, the motivational component of this study and the incentives given to the participants may explain the observed improvements. The pending completion of the data collection for the control groups may better explain these effects and demonstrate what can be specifically attributed to this intervention.

Despite the limitations of the study, there could be several important clinical implications to consider. While more research surrounding this topic is warranted, the present results support the potential of attention training as a nonpharmacological treatment approach to parents of children with behavioural disorders. Moreover, the results may provide useful insights into the merging of treatment and innovative technological advances.

Conclusions

The positive effect of attention training on emotional control may be compelling, and the strengthening of attention networks holds great promise for improvements in cognitive function. Further research may help us gain a more profound understanding of the relationship between attention and potential behavioural improvements, as well as the age and frequency at which such training programs may be more effective.

Acknowledgements

We would like to thank our team of attention trainers and members of the Raz Lab for their assistance. Dr. Raz recognises the support of the Canada Research Chair program, the Canadian Institutes of Health Research, and the Natural Sciences and Engineering Research Council of Canada.

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Appendix A: Letter of Invitation to Parents

To the Parents/Guardians of _________,

I am contacting you on behalf of our research group at the Cognitive Neuroscience Laboratory at McGill University.

We are conducting a research project exploring claims of improved intelligence and inhibitory control following a new computerized brain-training program. This novel training program uses age-appropriate computer games to increase attention. With your help and your child's participation we may develop interventions that can offer you the potential benefits associated with the training at no cost.

Your child has been randomly selected as a candidate to participate in our study. Your child's participation is voluntary and you should not feel any obligation to participate. Decision to participate in the study will not affect your child in any way.

If you are interested in the study and would like to know more, please let us know your decision by returning this letter **to your child's teacher before ___________.**

Please mark your choice with a ☑

☐ I am interested

__________________, parents/guardians of ________________ ***are interested*** *to know more about the study. We* **agree** *that Ms. Jenilee-Sarah Napoleon or Ms. Claire Champigny may contact us at (telephone number) _____________________ and/or via email (email address) ________________________________.*

Language preference: ☐ English ☐ French

☐ I am not interested

_________________, parents/guardians of ______________ ***are not interested to know more about the study.***

We are looking forward to hearing from you.

Yours sincerely,

Ms. Jenilee-Sarah Napoleon, Ms. Claire Champigny, Ms. Sheida Rabipour, and Dr. Elena Perez-Hernandez

Email: jenilee-sarah.napoleon@mail.mcgill.ca

Appendix B: Background Questionnaire

Background Questionnaire

Your contribution to this questionnaire will provide the researchers with context of your child's background. This includes language, socioeconomic factors, and extracurricular activities amongst others.

All responses will be kept confidential.

Instructions: Please fill in all spaces and mark the boxes where appropriate.

Section A: Caregivers' info

1) Your Name: ___________________________ Child name:________________

2) Name of 2nd child caregiver, if any: __________________________________

3) Street Address & Number: __________________________ 4) Apt #: _______

5) Postal code: _______________ 6) Home Phone: ___________________

7) Cell Phone: ___________ 8) Email: ___________________

9) Your relationship to child: ☐ Mother ☐ Father ☐ Non-biological caregiver

10) Your marital status:

☐ single ☐ married ☐ separated ☐ divorced ☐ widowed

☐ engaged ☐ annulled ☐ cohabitating

11) Mother (Caregiver 1): Current occupation: __________________

12) Mother (Caregiver 1): Previous occupation: _________________

13) Mother (Caregiver 1): Highest level of education attained:

☐ Less than 7th grade

☐ Junior high/Middle school (9th grade)

☐ Partial high school (10th or 11th grade)

☐ High school graduate

☐ Partial college (at least one year, includes CEGEP)

☐ College education

☐ Graduate degree

14) Father (Caregiver 2): Current occupation: __________________

15) Father (Caregiver 2): Previous occupation: _________________

16) Father (Caregiver 2): Highest level of education attained:

Less than 7th grade

☐ Junior high/Middle school (9th grade)

☐ Partial high school (10th or 11th grade)

☐ High school graduate

☐ Partial college (at least one year, includes CEGEP)

☐ College education

☐ Graduate degree

Section B: Language

1) What is the dominant language spoken in the household?
☐ English ☐ French ☐ Other: ______________

2) How many OTHER languages are spoken in the household? Please indicate which languages.
☐ 0 ☐ 1 ☐ 2 ☐ 3

3) Do specific members of the household communicate in certain languages to the child?
Eg. Mother speaks English to child; father speaks French to child; siblings speak English to child.

☐ Yes ☐ No

Please specify, according to the given example.

____

____

4) What is the language(s) of instruction at the child's day school, if applicable?
☐ English ☐ French

☐ Other: ______________ ☐ My child does not attend day school

5) What is the language of instruction at the child's behavioural program, if applicable?

☐ English ☐ French ☐ Other: _______________

☐ My child does not attend a behavioural program.

6) How many languages is your child fluent in (i.e. Able to understand and formulate sentences). Please circle.

1 2 3 4 5

7) Is your child learning any other language (other than English or French)? If so, please indicate which one(s):

___________________ ___________________ ___________________

8) If the answer to question 7 is "Yes", please indicate how many hours are spent studying that language per week.

☐ 1-3 hours ☐ 4-6 hours ☐ 7-9 hours ☐ +10 hours

Section C: Extra-Curricular Activities

Please indicate which of the following activities (if any) your child participates in.

☐ Art lessons ☐ Music lessons ☐ Sports lessons

☐ Martial arts lessons ☐ Tutoring ☐ Language lessons

☐ Playing chess, puzzles and/or other strategy games

☐ None ☐ Other: ___________________

Does your child play video games? ☐ Yes ☐ No

If yes, which kind: ________ (e.g. PlayStation, DS, PSP, PC games…)

How many hours used your child play video games daily? __________

Does your child play video games? ☐ alone ☐ with siblings or friends

Section D: Child Development

1) Were there any complications in the delivery of this child? If so, please specify:

____

2) Within the first 4 years of life, has the child experienced any fever greater than 40˚C or 103˚F? ☐ Yes ☐ No

If yes, did it require hospitalization? ☐ Yes ☐ No

3) Does your child experience blurry vision? ☐ Yes ☐ No

Is his/her vision corrected by use of glasses? ☐ Yes ☐ No ☐ N/A

4) Has your child ever required speech therapy? ☐ Yes ☐ No

Does he/she still require speech therapy? ☐ Yes ☐ No ☐ N/A

5) Please add additional comments.

____

____

Section E: Child's Programming

1) How many different schools has your child been in?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ +5

2) Is your child on a special behaviour program? If not, please ignore questions 3 and 4.

☐ Yes ☐ No

3) Please indicate the program's name: ______________________

4) How long has your child been in this program? _________________

Section F: Family Background

1) How many other siblings does your child have? _____

2) Does your child share a bedroom with other siblings? ☐ Yes ☐ No

If so, how many other siblings? ____

3) Is the child not living with either the biological or adoptive parents? ☐ Yes ☐ No

4) Has the child ever been in the care of local authorities due to family difficulties?

☐ Yes ☐ No

5) Has either of the child's parents used cannabis or other illicit drugs? ☐ Yes ☐ No

6) Have either of the child's parents had a history of problems with cannabis or other illicit drugs?

☐ Yes ☐ No If yes, please indicate when.

☐ In the past 6 months ☐ In the past year ☐ In the past 5 years

☐ In the past 10 years ☐ In the past 15 years ☐ N/A

7) Have either of the child's parents had a history of problems with alcohol or other substance abuse? If yes, please indicate when.

☐ Yes ☐ No

☐ In the past 6 months ☐ In the past year ☐ In the past 5 years

☐ In the past 10 years ☐ In the past 15 years ☐ N/A

8) Have either of the child's parents had a history of offence against children? ☐ Yes ☐ No

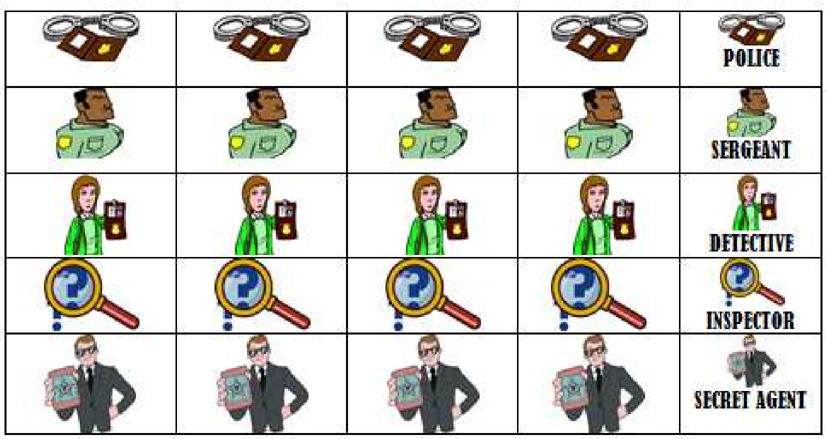
9) Has the mother ever been diagnosed with any mental illness (eg. schizophrenia, major depression and/or general anxiety? ☐ Yes ☐ No Please specify. ____________________

Please make any additional comments.

----------------------------- Thank you for your participation in this study. -----------------------------

Appendix C: Secret Agent Academy ID Card

Front of ID Card



Back of ID Card

Connecting Text

In our previous experimental piece, we aimed to examine how control networks operationalized by attention could regulate cognition, motion, thought and behavior across development. The following critical piece examines the legal aspect of the lucrative commercial market of brain training. Cognitive training is not a novel notion, despite the outpouring of brain training applications and programs that profit from the marketability of programs informed by neuroplasticity research (Boot & Kramer, 2014). In any activity, prolonged familiarity or practice leads to expertise in that specific process, or skilled behaviour. Lately, there has been increased interest in developing training programs that lead to improvement in or transfer-effects to a widespread array of cognitive skills or exercises that go beyond the tasks that were trained (Schubert, Stroback, & Karbach, 2014; Jolles & Crone, 2012; Hertzog, Kramer, Wilson, & Lindenberger, 2008) and is frequently linked with the goal of improving cognition or ameliorating the rate of age-related decline of cognitive abilities such as working memory, reasoning, and fluid intelligence, abilities that have been proven to predict performance in academic, workplace and extracurricular settings (Gray & Thompson, 2004; Gottfredson, 1997; Colom, Escorial, Shih, & Privado, 2007). Developmental researchers also use computerized training programs to investigate the improvement of cognitive abilities in children (Rueda, Rothbart, McCandliss, Saccomanno, & Posner, 2005; Thorell, Lindgvist, Bergman, Nutley, Bohlin, & Klingberg, 2009; Jaeggi, Buschkuel, Jonides, & Shah, 2011; Loosli, Buschkuegl, Perrig, & Jaeggi, 2012), including those from disadvantaged backgrounds (Mackey, Hill, Stone, & Bunge, 2011) and those with learning and behavioural difficulties (Kirk, Gray, Riby, & Cornish, 2015; Klingberg et al., 2005; Holmes, Gathercole, & Dunning, 2009; Dunning, Holmes, Gathercole, 2013; Klingberg, Forssberg, Westerberg, 2002). The following manuscript discusses these programs, their effectiveness and marketing tactics.

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Manuscript 2: Critical Piece

Legal Aspects of Brain Training

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Abstract

In recent years, neuroplasticity findings have given way to a very lucrative brain training market. Little is known about the concrete gains brain training programs can produce and whether these gains can be transferred to real life abilities. Many of the scientific studies that accompany these programs have serious methodological limitations. This critical piece aims to uncover the aggressive marketing practices of brain training companies. It also seeks to provide critical information concerning the assessment of generalizability of such cognitive gains to events in the real world. Since there is still controversy about how to measure generalization and transfer effects to daily life, we discuss the validity of advertising claims and the regulations behind them.

Keywords: *brain training market, cognitive training, transfer effects*

Introduction

Brain training, the process of enhancing, rehabilitating, or simply maintaining cognitive function using deliberate cognitive exercise (Rabipour & Davidson, 2015), is increasing in popularity. Yet, the practice remains contentious as few have addressed the legality of cognitive training programs and their claims. This chapter discusses hyperboles in the industry of brain training, aggressive marketing techniques, conflicts of interests in scientifically proven studies, and the regulations behind these programs.

Although the adult brain was once seen as a rather static organ, it is now clear that the organization of brain circuitry is constantly changing as a function of experience and learning (Slagter, Davidson, & Lutz, 2011). Not only long-term expertise, but also relatively short practice has been associated with neural changes in adults. For instance, performing a five-finger piano exercise for two hours on five consecutive days gave rise to an expansion of primary motor areas that represent the finger muscles, which complemented improved performance (Pascual-Leone et al., 2005).

Based on the neuroplasticity of the brain, numerous commercial software benefit from computerized training, offering the comfort and privacy of brain training exercises at home (Rabipour & Raz, 2012). Each year, the market for brain training products produced by companies like Lumosity, CogMed, and Posit Science brings in approximately $1.3 billion of profit across the world (Sharp Brains, 2014). Lumosity, which offers web-based tasks designed to improve cognitive abilities such as memory and attention, boasts 50 million subscribers and advertises on many different platforms (Thompson, 2014), such as television and radio advertisements on networks including CNN, Fox News, the History Channel, National Public Radio, Pandora, Sirius XM, and Spotify. The company also advertises through emails, blog posts, social media, and on their website, "Lumosity.com". Additionally, they use Google AdWords to redirect traffic to their website, by purchasing hundreds of keywords related to memory, cognition, dementia, and Alzheimer's disease (FTC, 2016). CogMed claims to be "a computer-based solution for attention problems caused by poor working memory," and BrainHQ will help you "make the most of your unique brain." Brain games, which are becoming more widespread, are mainly marketed at the parents of young children and aging adults (Owen et al., 2010). Programs allure parents and professionals searching for symptom relief, a possible cure, or an advantage in a competitive culture (Shipstead, Hicks & Engle, 2012). The promise of all of these products, whether implied or explicit, is that brain training can make you smarter and make your life better (Stanford Center on Longevity, 2014). However, the companies that market brain training games are often taking advantage of buyers by making inflated and misleading claims that their games can slow or reverse age-related memory decline and improve other cognitive functions.

In a Consensus on the Brain Training Industry from the Scientific Community– a letter signed by 73 health professionals worldwide – scientists denounced the hype by both brain training companies and the media (Stanford Center on Longevity, 2014). Many scientists recoil at audacious advertisements claiming enhancements in the speed and efficiency of cognitive processing and dramatic gains in aptitude (Thompson, 2014). Experts believe that these advertisements may be detrimental in the sense that these brain games could have an effect opposite to the claim; by playing these games, the participant becomes less socially and physically active. Others suggest that the advertisement strategies of brain training companies are exploiting the anxiety of adults confronted with old age for commercial purposes. Many people are concerned about the possible loss of cognitive abilities, and the advertising of brain gaming products offers reassurance and attracts the worried public. Buyers are told that playing these games will make them more intelligent and attentive, and increase their ability to learn faster and more efficiently (Stanford Center on Longevity, 2014). It is important to keep in mind that scientists are not trying to discredit neuroplasticity; nevertheless, research based on most of these brain training programs have not yet shown global effects relevant to everyday life.

In reaction to the Consensus on the Brain Training Industry, 127 scientists from 18 countries sent an open letter to the Stanford Center for Longevity. They voiced their disapproval of the exceedingly critical stance on the unfolding science of brain training and the denigration of the potency of all brain training exercises (Cognitivetrainingdata.org, 2014). The letter strongly opposed the critique of cognitive training exercises made by the Stanford Centre for Longevity, which stated that there is no convincing scientific evidence that brain training offers consumers a scientifically supported opportunity to reduce or reverse cognitive decline. They disputed that there is mounting evidence that some brain exercises do offer benefits. As a response to the possible detrimental effect of brain training, some have argued against the criticism that at home brain training programs may lead to being less socially and physically active. Certain programs include multiplayer games where children can play against their friends. Additionally, the combination of cognitive training and physical activity has been reported to show stronger effects than pure cognitive training in older adults. Researchers demonstrated that combining cognitive training and physical activity lead to stronger long-term effects on attention (Rahe, Petrelli, Kaesberg, Fink, Kessler, & Kalbe, 2015). While many studies have suggested that brain training may offer some benefits that we cannot ignore, specialists remain cautious in relation to the claims behind many brain training games and applications that have far surpassed what science has been able prove so far. The letter also states that “no one should say or imply that products have scientific evidence when there is no or little evidence for those claims” (Cognitivetrainingdata.org, 2014).

Laws in Place

Some laws in Canada and the United States could potentially apply to brain training companies. However, whether brain training companies have technically broken any laws is unclear as these programs are not sold under the premise of being "medical equipment," nor do they claim to replace conventional medically approved methods. In Canada, the Competition Bureau, an independent law enforcement agency, ensures that Canadian businesses and consumers prosper in a competitive and innovative marketplace. It acts as a civil provision and prohibits false representations to the public about the performance, efficacy, or lifespan of a commercial product that is not based on adequate and proper testing (Paragraph 74.01(1)(b)). In other words, if an advertisement influences a consumer to buy or use their product on unproven claims, the company becomes subject to the Act. "Advertising" and "advertisement(s)" are defined as any message (the content of which is controlled directly or indirectly by the advertiser) expressed in any language and communicated in any medium to Canadians with the intent to impact their choice, belief or conduct (Advertising Standards Canada, 2014). If a court determines that a person has engaged in a manner contrary to Paragraph 74.01(1)(b), it may order the person to publish a corrective notice and or to pay an administrative penalty. In the latter case, fines can go up to $750,000 for individuals and $10,000,000 for corporations in the case of a first time occurrence. The phrase "adequate and proper testing" has not been defined by the legislation in order to preserve flexibility in an increasingly complex and highly technical fluid of expertise (Competition Bureau, 2014). Furthermore, Paragraph 74.01(1)(b) requires an advertiser to offer evidence in support of the tests, after which it is open to the Commissioner to lead evidence to show that the testing is not "adequate and proper." Performance claims that raise a question under the Act fall into two broad categories: those that are inappropriate in relation to the actual test results and those that are based on poorly designed test methodologies. Businesses should not make any performance claims unless they can be bolstered (Competition Bureau, 2014).

The misleading advertising and labelling provisions enforced by the Competition Bureau forbid deceptive representations for the purpose of promoting a product or a business interest and encourage the provision of sufficient information to allow consumers to make informed choices. Even if the evidence is scarce, most commercial brain training products maintain and advertise that their programs improve specific skills. Also, the lack of transferability of training to cognitive domains unrelated to the ones trained in their program, raises the question of why the majority of brain training companies continue to make false claims despite what seem to be violations of these standards.

Advertising Standards Canada (ASC) administers the *Canadian Code of Advertising Standards,* or *Code.* The Code sets the criteria for adequate advertising and forms the basis for the appraisal and judgment of consumer and advertising disputes (Advertising Standards Canada, 2014). According to the Code, advertisements must not change the true meaning of statements made by professionals or scientific authorities. Advertising claims must not suggest that they have a scientific basis that they do not truly possess. Any scientific, professional, or authoritative claims or statements must be pertinent to the Canadian context, unless otherwise clearly stated.

The amount of complaints by Canadian consumers about exaggerated health claims in advertising increased significantly in recent years. Consumers submitted considerably more complaints about "complementary and alternative medicine" services according to an annual report by ASC (Krashinsky, 2014). A number of those complaints filed were upheld and investigated. For instance, a spa in British Columbia removed ads online saying that its facials "actually reversed the aging process" (as cited in Krashinsky, 2014). Since the spa owners had no scientific proof to justify that statement, ASC found that it violated clauses in the Canadian Code of Advertising Standards that necessitate clarity and accuracy. One of the clauses states that claims in ads must be supportable with research that follows accepted standards. Since the brain training programs are not Canadian products, the standards of the Competition Bureau do not apply.

The United States guidelines are similar to the Canadian ones. The Federal Trade Commission (FTC) is an independent agency of the U.S. government established in 1914 by the Federal Trade Commission Act. It is involved in the oversight of the online advertising industry and its practice of behavioural targeting (FTC.gov, 2014). The Bureau of Consumer Protection has a mandate to protect consumers against unfair or deceptive acts or practices in commerce. In the case of deception practices, there must first be a representation, omission, or practice that is likely to mislead the consumer, and in the case of omission, the Commission considers the implied representation understood by the consumer. A misleading omission occurs when information is not disclosed to correct reasonable consumer expectations. Second, the Commission examines the practice from the perspective of a reasonable consumer being targeted by the practice. Finally, the representation or omission must be material. That is to say, it would have changed consumer behaviour. In the case of unfair practices, Courts have identified three main factors that must be considered in consumer unfairness cases: whether the practice injures consumers, whether the practice violates established public policy, and whether is the practice is unethical or unscrupulous (FTC.gov, 2014).

The FTC regulates advertising claims that companies make about their products. The Division of Advertising Practices in the FTC also brings administrative lawsuits to stop unfair and deceptive advertising (FTC.gov, 2014). The Division's enforcement priorities include monitoring and discontinuing deceptive Internet marketing practices that develop in response to public health issues (FTC.gov, 2014). The Division manages and addresses existing consumer protection issues with state, federal, and international law enforcement agencies, in addition to industry self-regulation groups. These initiatives include working with the Food and Drug Administration (FDA) to combat fraudulent products on the Internet with joint warning letters (a letter from the FTC and a letter from the FDA) (FTC.gov, 2014).

Section 5 of the FTC Act requires that advertisers have a reasonable basis to support their statements and implied advertising claims before they are disseminated to ensure that such claims are veridical and non-deceptive (FTC.gov, 2016). Advertisers must also have exhaustive and accurate scientific support to substantiate claims for products that declare they prevent or treat health or disease-related conditions (FTC.gov, 2016). When explicitly asked about the FTC's regulation of brain-training products, an FTC representative claimed that the commission does not speculate about whether it will take action in a specific area (Goodman, 2014). It seems that in spite of the regulation, and despite the fact that these claims are questionable and that supporting research is in desperate need of more substantial evidence, advertisers still find ways to deceive consumers in ways that are either legal or technically illegal but often disregarded.

FDA Regulations

Although some mobile applications that include brain training meet the definition of a medical device, a representative for the FDA stated that brain games that pose a low risk, such as those intended to help improve cognition, "would likely fall under the agency's enforcement discretion." According to the FDA, when software or applications are "marketed, promoted or intended for use in the diagnosis of disease or other conditions, or in the cure, mitigation, treatment, or prevention of disease, or otherwise meet the definition of medical device, the FDA intends to exercise enforcement discretion" (FDA, 2014) – the FDA will not implement regulatory requirements with respect to such applications (Guidance of FDA Regulation of Medical Mobile Apps, 2014). It is unclear why the FDA will not oversight nor regulate apps that help users self-manage their condition without providing specific treatment or treatment suggestions (FDA, 2014). As a result, these limitations create a loophole for companies within the brain training industry to market directly to consumers all in the midst of avoiding FDA regulations.

Several programs are now going through the approval process. They want doctors and regulatory agencies to validate their products (Thompson, 2014). A professor from University of California at San Francisco, Dr. Adam Gazzaley, recently announced that he would seek the FDA recognition of his lab-developed video game, NeuroRacer, a supposedly safe and effective device for the treatment of cognitive decline in the elderly (Greely, 2014). This program uses self-adjusting difficulty settings to engage the brain in a way that strengthens multi-tasking skills. It was suggested that if it gets government approval, it might become a kind of cognitive Lipitor or Viagra, a game that your doctor could prescribe for your aging mind (Thompson, 2014). Dr. Michael Merzenich, Chief Scientific Officer of Posit Science, is also seeking FDA approval for a game that has shown success in treating hemispatial neglect in stroke patients, an illness that causes patients to psychologically neglect one side of their vision and occasionally neglect a limb (Thompson, 2014). These companies' main task is to convince the FDA that they have the data to prove that the beneficial effects of these programs are more than a virtual reality (Greely, 2014). According to the FDA's regulatory jurisdiction, its definition of a "medical device" is quite broad and can encompass such a technology (FDA, 2014). Regulatory authorities such as the FDA have as their mandate to insure that products are both harmless and effective. If a certain brain training game is effective, then by definition, it has enhanced cognitive function. Many scientists aim to expand the repertoire of brain-therapeutic neuro-technologies, especially in a way that moves away from pharmacological interventions (Greely, 2014). Yet, several believe that time has not occurred yet.

User Agreements in Brain Training Programs

At this time, brain training companies construct their user agreement in such ways to limit liability for false claim. In the case of Lumosity, except with their written permission, one is not allowed to use or distribute Lumosity for their own scientific or clinical research purposes. One must also agree that the "use of Lumosity is at their own sole risk and that Lumosity is provided on an "as is", "as available" basis, without warranties of any kind, either expressed or implied." This particular clause in Lumosity's user agreement negates its exaggerated marketing claims. When you sign up, you also agree that you and Lumos Labs (makers of Lumosity) "will resolve through binding arbitration any dispute, claim or controversy between us arising out of or relating in any way to Lumosity or your use thereof" (Lumosity, 2014). In other words, if you feel as though you are not seeing any improvements as a result of your training, the user agreement forbids you from taking legal action.

In a similar vein, Brain HQ binds their users with terms and conditions. To begin with, BrainHQ claims that the content of their site is for "informational purposes only and are not intended to substitute for professional medical advice, diagnosis, or treatment [...]. Likewise, BrainHQ states that one should not interpret "Your Report" or any other site content as recommending any specific treatment plan, product or course of action." Clauses such as these allow brain training companies to offer these products and avoid FDA regulations. Nonetheless, for many years, federal regulators ignored the brain training industry's operations (Goodman, 2014).

Brain Training Programs

In the last few years, many commercial, software-based training programs have been established. One of the most well-known for children is CogMed, which is available in 30 countries and is extensively used. This program is based on eight different exercises that involve both visuospatial and verbal working memory tasks, in which the difficulty level varies adaptively throughout the training (Shipstead, Hicks & Engle, 2012). It involves training on working memory exercises for 5 days per week over a timeframe of 5 to 6 weeks (Klingberg, 2007). CogMed suggests that results have proven that the gains persist substantially beyond training for the vast majority and that it can have major effects on generalized cognitive ability (Shipstead, Hicks & Engle, 2012). The CogMed website claims that "CogMed Working Memory Training is a solution for individuals who are held back by their working memory capacity. That means several large groups: children and adults with attention deficits or learning disorders" and that "when you improve working memory, you improve fluid IQ [...] you will be better able to pay attention, resist distractions, self-manage, and learn" (as cited in Melby-Lervag & Hulme, 2013, page 3). Other commercially available working memory training programs include Jungle Memory, which is based on three different tasks, and Cognifit, which is based on auditory, visual, and cross-modal working memory tasks. The Jungle Memory website states that the program will help children with Attention-Deficit Hyperactivity Disorder (ADHD), dyslexia and language impairments, dyspraxia and sensory integration difficulties, and autism spectrum disorders, as well as children with low grades. It also claims that "Jungle Memory improved IQ, working memory, and grades

[…] Jungle Memory is the only brain training program proven to improve grades immediately after use" (as cited in Melby-Lervag & Hulme, 2013, page 3).

On their website, the makers of Timocco – a virtual computer program with games specifically tailored for children with ADHD, autism spectrum disorders, cerebral palsy, developmental coordination disorder and learning disorders – claim that Timocco is a "cutting-edge virtual motion gaming system that accelerates the development of motor and cognitive skills including bilateral coordination, crossing the midline, hand-eye coordination, early learning, communication, short-term memory and team work" (Timocco, 2015). Yet, the published research section listed on the website includes two separate case studies of a five year old child (Tresser, 2012; Tresser, 2011). The research studies section includes four papers. The studies included measures on the 'sit-to-stand' skill in adult rehabilitation; a study on the connection between use of a dominant hand in virtual reality games; a case study of a clinical intervention on a four-year-old with a suspected diagnosis of ADHD that suggested that the child exhibited lower levels of distraction and hyperactivity following Timocco sessions; a pilot study of sixty-five children ages three to seven, of whom thirty had been diagnosed with ADHD and twenty-four with cerebral palsy (Tresser, Rabinovitch, Sahar, & Zelnik, n.d.). The study's results demonstrated that ninety percent of the children with ADHD displayed immediate improvement in their ability to remain attentive in structured forty-minute tasks. In the latter two studies, the papers did not however discuss the structure of the task, the measures used to assess the children's improvement, the settings, nor the number of sessions in which the children played Timocco. It remains unclear how Timocco is able to state that "Timocco develops motor, cognitive and communication skills" based on the limited research evidence.

The CogMed program, which is publicised as effective in both healthy and pathological populations, both young and old, is among the most carefully studied of these brain training products (Shipstead, Hicks & Engle, 2012). An initial study suggested that children with ADHD and healthy adults who trained with constituents of the CogMed program displayed widespread improvements in cognitive control and general fluid intelligence, with supplementary reduction in symptoms related to ADHD in the pathological population. The findings were also replicated in healthy adults, even though the studies were unclear about the likelihood of improvements due to test–retest effects (Westerberg & Klingberg, 2007), which are influences on performance that arise from practicing a task (Heiman, 2002). A subsequent study in children with ADHD showed significant improvements on measures of attention and intelligence compared to controls. Participants maintained progress three months after concluding 25 sessions of visuospatial, backward-digit, and letter-span tasks from the CogMed program. Remarkably, still, children randomly assigned to the control group displayed increased scores at the 3-month evaluation period, which could also point to an inadequate level of difficulty in the testing measures used. Additionally, parent - but not teacher - reports showed decreases in ADHD symptoms. Even if this study appeared to demonstrate generalizability to cognitive areas unrelated to the training, the participants did not improve on measures of intelligence, reading, or mathematical reasoning. Moreover, the measures taken after the completion of the study did not include comparisons to the control group (Rabipour & Raz, 2012).

So far, most brain training programs do not appear to be supported by any detailed task analysis or theoretical explanations of the transfer effects. Researchers concluded that the assertions made by CogMed are essentially uncorroborated, and suggest that future research focus on developing theoretically motivated accounts of working memory training (Shipstead, Hicks, &

Engle, 2012). Explanations of the mechanisms by which these training systems would be anticipated to improve working memory capacity may clarify uncertainties. Instead, these programs seem to be grounded on what might be seen as a quite naïve “physical-energetic” model such that repeatedly “loading” a limited cognitive source will lead to it increasing in ability, analogously to firming a muscle by repeated use (Melby-Lervag & Hulme, 2013).

Hyperboles and Aggressive Marketing in the World of Brain Training

Hyperboles, defined by Oxford dictionaries as “exaggerated statements or claims not meant to be taken literally,” reign in the commercial world and do not spare the brain training industry (Thompson, 2014). In advertising, the small, slim and short-lived advances are often publicised as general and lasting improvements of the mind and brain (Stanford Center on Longevity, 2014). LearningRx’s slogan is “Train the Brain, Get Smarter”; the company’s website claims that it has “developed the nation’s most powerful and effective brain training program […] LearningRx brain training delivers results. The training works for students of all ages seeking all types of mental and academic improvement […] It even helps men and women suffering from traumatic brain injury recover lost brain function quickly and more completely.” The vocabulary that these companies use demonstrates overconfidence and offer promises that cannot always be kept. Lumosity encourages clients to “challenge your brain with scientifically designed training” (Thompson, 2014). Brain+ Chief Executive Officer Kim Baden-Kristensen recently claimed that her brain training application was “built on cutting-edge neuroscientific insights, methods and training principles that have been validated scientifically” (Thompson, 2014). Indeed, the programs were designed by scientists but they lack rigorous scientific review. It is the norm for companies to emphasize the advantages and exaggerate potential benefits of their products. In the industry of brain training, advertisements reassure consumers with vows based on supposedly firm scientific evidence, claiming that the games were tailored by neuroscientists at the best universities and research centers. Some offer lists of comments from science scholars and make scientific articles about brain training available to the public.

Conflicts of Interests in "Scientifically Proven" Studies

A conflict of interest (COI) is defined as a set of conditions in which professional acuity concerning a primary interest like the professional duties of an individual or the validity of research, tends to be excessively impacted by a secondary interest such as financial gain (Thompson, 1993). The evaluation of training effectiveness is an enduring problem of cognitive intervention research (Noack, Lovden & Schmiedek, 2014). Private industry plays a significant part in producing and distributing new scientific knowledge, but given strong monetary incentives, experts associated with private industries face noteworthy COIs, which may consciously or unconsciously influence the way they construe and discuss scientific evidence (Silverman et al., 2010). The brain training market occasionally produces COIs that may possibly bias the scientific integrity of published work. The scientific articles are often directly linked to the companies of the products being sold (Stanford Center on Longevity, 2014). Similarly to pharmaceutical and medical device corporations, suppliers of cognitive exercise programs often fund studies assessing their product or allocate product analyses to academic stockholders. These COIs may hinder the objectivity of studies by encouraging the oversight of results unfavorable to the preferred outcome or the reporting of results that are advantageous to the funding corporations (Rabipour & Raz, 2012). Reviews have shown that industry-funded studies may be several times more likely to yield results and conclusions in favour of the sponsoring company than studies of the same agents that are funded by government or non-profit organizations, even after correcting for various measures of study quality (Silverman et al., 2010). In addition, most brain training companies run their own experiments for their products; hence, there is monetary incentive to yield positive results. Often, these studies also have a number of participants that is too small to yield an acceptable effect size and, as result, to offer statistically valid conclusions (Goodman, 2014). Meta-analyses or studies with a high number of participants are rarely integrated in their advertising (Stanford Center on Longevity, 2014). Authors with relations to the industry may also overextend the explanations of their results by accentuating statistical significance while disregarding small effect sizes that would show little or no clinical significance (Turner, Matthews, Linardatos, Tell & Rosenthal, 2008). Such COIs create challenges for professionals and consumers who are trying to interpret the scientific literature, as they must find ways to judge the scientific merits of research while concurrently taking into account how COIs have shaped the very same research (Silverman at al., 2010). Thus, COIs possibly impede the integrity of research, as one of the goals of research is for laypeople to trust and rely on professional judgment. Scientists who have any financial connection with the industry should avoid states of conflict, such as financial gain. They should also minimize interfering with studies that could lead people to suppose that one's professional judgment has been improperly influenced (Thompson, 1993).

On the website of brain industry leader Lumosity, consumers can click on a tab to "Learn More About the Research." They list thirteen studies, eight of which are completed in their own laboratories, the *Lumos Labs*. One study emphasises the benefits of the company's brain training exercises in the classroom. Researchers asked over eight hundred students to complete ten hours of training with Lumosity games over the course of the semester. The company's researchers claimed that those students exhibited larger improvements than the four hundred other students who did not participate in the brain training conditions (Goodman, 2014). However, the improvements remain questionable. The children scored better on the "Brain Performance Test," an assessment that was also produced by Lumosity. The company did not take the children's grades nor standardized test scores into consideration. Dr. Daniel Sternberg, a study author and senior data scientist working with Lumosity, explained that the Brain Performance Test is a computerized version of standard neuropsychological assessments. The common belief that commercially available computerized brain training programs increase wide-ranging cognitive function in the general population lack empirical support (Owen et al., 2010). As mentioned by Dr. Randall Engle, psychology professor at the Georgia Institute of Technology, "if these companies were serious about doing a real test of their product, they would fund an independent agency to supervise these studies and would have the studies done by a researcher that is skeptical about the product. If there is improvement under those circumstances, then it is probably real" (as cited in Goodman, 2014, page 4). Many scientists agree that "evidence is stronger if run independently, funded independently, run at multiple sites, and if it evaluates program benefits by comparison with 'active' control activities" – activities that one would take part in on a regular basis, such as physical exercise and reading (Sharp Brains, 2014).

Moreover, although some brain training companies offer lists of credentialed scientific consultants and keep archives of scientific studies relevant to cognitive training, the cited research is often only vaguely related to the scientific claims of the corporation and to the games they sell (Goodman, 2014). Dr. Ulman Linderberger, director at the Max Planck Institute published an experiment that demonstrated that 100 days of cognitive training yielded a "relatively minor" improvement in working memory (Schmiedek, Lövdén, & Lindenberger, 2010). However, soon after, a German brain-training firm cited his paper on its website, to show support in relation to the effectiveness of cognitive training, despite the fact that their product was not used in Dr. Linderberger's research. The company even appropriated the Max Planck logo (Thompson, 2014).

Dr. Thomas Redick, a cognitive psychologist at Purdue University, claimed that "the truth is that despite 15 years of research, we do not actually know how or if, really brain training games work" (as cited in Thompson, 2014, page 6). Researchers show that there are significant individual differences that determine training and the transfer of the acquired capacities to other activities (Jaeggi, Bushkuehl, Jonides, & Shah, 2011). Brain training benefits are frequently stimulus- or content-specific rather than process-specific (Stagter, Davidson, & Lutz, 2011). At times, research on training and transfer effects produces varying results (Jaeggi, Bushkuehl, Jonides, & Shah, 2011). Numerous systematic reviews have addressed the effects of working memory and cognitive training programs (Melby-Lervag & Hulme, 2013). The conclusions drawn from these analyses vary significantly. Some of the reviews concluded that working memory training has very favourable prospects. For instance, some researchers indicated that "the results from individual studies encourage optimism regarding working memory training as a tool for general cognitive enhancement" (Morrison & Chein, 2011) and Klingberg (2010) declared that "the observed training effects suggest that working memory training could be used as a remediating intervention for individuals for whom low working memory capacity is a limiting factor for academic performance or in everyday life." This dissimilarity in the conclusions drawn from present analyses almost certainly reflects the fact that there are large deviations in results across studies in the field. Currently available working memory training programs have been examined in a wide range of studies involving typically developing children, children with cognitive impairments (particularly ADHD), and healthy adults.

A critical subject is whether transfer effects are maintained for a significant period following the completion of the brain training program, as this often makes headlines in the brain training market. Instead of generalizability, the progress observed in many programs may arise because of other reasons, such as training to task (Rabipour & Raz, 2012). In a six-week study with 11,430 participants where subjects trained several times a week on cognitive tasks, researchers observed improvements over time. Yet, no evidence for transfer effects to untrained tasks was found, even cognitively closely related ones (Owen et al., 2010). Scientists further propose that future research should not explore whether brain training works, but rather should decipher what training procedures and conditions result in the greatest transfer effects, investigate the underlying neural and cognitive mechanisms behind neuroplasticity, and examine for whom brain training is beneficial (Jaeggi, Bushkuehl, Jonides, & Shah, 2011). More systematic research is necessary to reproduce, explain, combine and enlarge results from brain training games (Stanford Center on Longevity, 2014).

Although some experiments find some improvements and others find none, brain training companies claim that the intelligence of participants will improve after engaging in their program. The generalizability of brain training symbolises one of the main distinguishing features of publicly distributed programs. With limited data to uphold advertised claims, consumers of brain training often spend substantial resources chasing programs that promote uncorroborated and idealistic results (Rabipour & Raz, 2012). Advertisements assert that these tests can increase activity in specific areas of the brain and therefore overall intelligence.

Effectiveness of Cognitive Training

Plasticity is a normal phenomenon and research has demonstrated that brain maps are continuously changing (Doidge, 2007). The Hebbian theory argued that the structure of neurons can be transformed through experience (Hebb, 1949). Based on theories and his personal research, Merzenich – Chief Scientific Officer of BrainHQ – believed that if brain maps could be altered, then there was a reason to expect that individuals with problems in brain map-processing areas – people with learning disabilities, psychological disorders, strokes, or traumatic brain injuries – might be able to create new brain maps if he could help them produce new connections, by getting their healthy neurons to fire and wire together (Doidge, 2007). Merzenich laments the belief that learning disabilities cannot be overcome, "it's just so destructive to imagine that your neurological resources are permanent and enduring and cannot be substantially improved and altered" he says (Doidge, 2007, page 69).

Though some scientists dispute the efficacy of several commercial brain training software, evidence shows that some programs facilitate noticeable advances in cognitive function. Studies on cognitive training show improvements that include a broad variety of cognitive and everyday activities, and that carry on for quite some time and demonstrate favorable changes in real-life indicators of cognitive capacity (Sharp Brains, 2014). With the help of other scientists, Merzenich developed Fast ForWord, a cerebral cross-training program tailored for children with language impairments and learning disabilities. Results demonstrated that when compared to the control group, children who went through Fast ForWord training made substantial progress on standard speech, language, and auditory-processing tests, had better than normal language scores, and maintained their improvements when re-assessed six weeks after the training ended (Doidge, 2007). He also launched a new company, Posit Science, and created BrainHQ. The goal of this brain training program is to help people preserve the plasticity of their brains as they get older. He believes that the drugs available for cognitive decline only provide short-term improvements, as they are designed to block the processes that occur as neurons die and atrophy. At this time, sixty-seven published studies conducted at a variety of academic institutions are listed on the Brain HQ website. These studies show improvements in cognitive performance, auditory memory, visual memory, ability to perform daily tasks, driving safety, processing speed, and health-related quality of life based on the exercise technologies in BrainHQ (BrainHQ, 2015).

Evidence that demonstrates effective interventions is mounting (Jaeggi, Bushkuehl, Jonides, & Shah, 2011). As mentioned above, in an issue of last year's *Nature*, Gazzaley proved that a brain training game he developed, called NeuroRacer, could be a treatment for the infirmities of elderly brains (Anguera et al., 2013). The improvements that Gazzaley demonstrated in his study stood apart, as he showed that the ameliorations could carry over into daily life and that the results of training were still present six months after the participants completed the experiment (Anguera et al., 2013). A few other studies have shown lasting benefits. A recent study published in the *Journal of the American Geriatrics Society* uncovered that seniors who participated in brain training to boost memory, reasoning, and processing speed performed better on reasoning tasks than a control group ten years after the completion of study (Rebok, 2014). Yet, as of now, neither NeuroRacer nor the exercises used in Rebok's study are available to the general public (Goodman, 2014).

As research in the area of cognitive training continues, it remains probable that training programs established in the future will display better generalization. It also remains possible that these online training programs, if applied to clinical groups such as children with ADHD, would yield clear changes in precise symptoms (Melby-Lervag & Hulme, 2013). At this time, key treatments for developmental psychopathologies such as ADHD frequently involve psychotropic medications, which may display minimal effects in a proportion of individuals. Moreover, these effects may weaken over time and can produce a number of undesirable side effects. Consequently, parents and professionals are often hesitant to welcome drug-based therapy in spite of the lack of safe and effective treatment alternatives. Recent claims also complicate the issue by declaring that some psychiatrists may have undisclosed connections with drug companies, which in turn biases the scientific research surrounding the fabrication and distribution of medication for children and adolescents. Due to the limitations in pharmacological-based medications, brain training may represent an attractive complement to usual pharmacological treatment (Rabipour & Raz, 2012). Dr. George Rebok of Johns Hopkins University declared "colleagues and I spent many months analyzing data from more than 150 publications and concluded that cognitive training can improve cognitive abilities" (Sharp Brains, 2014; Kueider, Parisi, Gross, & Rebok, 2012). Dependent on properly controlled experiments, brain training is a revolutionary approach with the possibility to alter the scene of non-pharmacological treatment.

Recent Events

The consequences of inflamed claims have begun to be observed in the brain training market. Recently, in line with the aforementioned arguments, Lumos Labs, the makers of Lumosity, co-founder and former Chief Executive Officer Kunal Sarkar, and co-founder and former Chief Scientific Officer Michael Scanlon were subject of a lawsuit claiming that they deceived consumers with scientifically unfounded claims that Lumosity games could help users perform better in academic and workplace settings, and diminish or delay cognitive impairment related to age and other serious health conditions (FTC, 2016). The company that creates the widely promoted brain training program has agreed to settle FTC charges. As part of the settlement, Lumos Labs, will pay $2 million in redress and will notify its subscribers of the FTC action and facilitate their option to cancel their automatic renewal to avoid being charged in the future (FTC, 2016).

Following this decision, Commissioner Julie Brill of the FTC issued a separate statement stating "I write separately to voice my strong support for this action, and to express my concerns regarding the marketing of brain training programs going forward. In particular, I caution Lumosity and other companies about making representations that overstate the benefits of these products or misleadingly imply that improvements in the game setting transfer to real-world benefits."

What's Next?

So far, many neuroscientists agree that there is little evidence that the majority of these games counter the mental deficits that accompany getting older (Stanford Center on Longevity, 2014). Even though a few programs appear to yield measurable improvements in their target population, many others lack scientific validity behind their allegations. Brain training interventions on the market claim to improve general mental capacity, yet, the scientific evidence for these claims is sparse. Cognitive training programs may increase performance on a particular subset of abilities or tasks, but the generalizability of the benefits to other spheres is rare (Rabipour & Raz, 2012). Again, these observations do not imply that the brain does not remain malleable, even through old age. Even with the increasing popularity of such products, their huge potential, and the cumulative indication both supporting and refuting the effectiveness of training, few articles have systematically reviewed the evidence surrounding cognitive programs (Rabipour & Raz, 2012). Dr. Alvaro Fernandez, CEO of Sharp Brains, believes that the concept of brain fitness will one day be as common and as recognized as physical exercise. At this time, he claims the industry may be promising more to consumers than it can currently deliver. “In principle, everyone can benefit from this, just like everyone can improve their physical fitness, but it has to be personalized and it has to be relevant to the individual, but we’re not there right now,” he says (Goodman, 2014).

Conclusion

Brain training constitutes a profitable market and has meaningfully affected society. From allegations of improving the symptoms of psychopathologies and neurological deficiencies to claims of increasing cognitive skills among the healthy, commercialized software and interactive programs gradually grasp the attention of parents, educators, students, and clinicians (Rabipour & Raz, 2012). Extensive apprehension about cognitive decline in the aging population and preoccupation with maximizing productivity in school and at work have generated a society of brain trainers that spare little expense on improving cognitive ability (Rabipour & Raz, 2012).

Yet, claims promoting brain games are frequently exaggerated and at times outright misleading (Stanford Center on Longevity, 2014). Scientists determined that the majority of current memory training programs appear to produce short-term, specific training effects that do not generalize to other activities/skills (Melby-Lervag & Hulme, 2013). In a meta-analytic review, researchers found no convincing evidence of the generalization of working memory training to other skills such as nonverbal and verbal ability, inhibitory process in attention, word decoding and arithmetic (Melby-Lervag & Hulme, 2013).

Some experts believe that government officials tolerate advertisers using wildly exaggerated, farfetched or unclear claims for a product or service because the advertisers think that nobody could possibly take the claims seriously or be misled by them (Cowley, 2006). The results of a study demonstrate that even though clients are able to identify exaggerated claims as less credible than factual claims, their brand evaluations are overestimated after exposure to exaggerated claims (Cowley, 2006). Scientists' explanation is that during the process of comprehension, claims are accepted before being discredited. The temporary acceptance of the claim affects memory, even after the claim is understood as an exaggeration. Findings support the theory "that every encounter with misinformation or an exaggerated claim can potentially affect future behaviour, even if the consumer realizes that the claim is false" (Gilbert, Tafarodi, & Malone 1993). In relation to brain training, it seems that consumers do not know what to believe or how to properly evaluate brain training programs.

When it comes to regulations that could apply to the brain training market, the FTC – who regulates advertising claims that companies make about their products – has recently taken action in the area of brain training programs, as aforementioned. On the other hand, the FDA intends to apply its regulatory oversight only to applications that are medical devices and whose functionality could pose a risk to the patient's safety if the application were to not operate as planned (Mobile Medical Applications, 2013). Since brain training programs pose low risks to consumers, they fall under the agency's enforcement discretion. As a result, what is difficult is the limitation of the law that has minimal legislation in place for this type of advertising. Over the last decade, the emergence of new technology has made it harder for courts or organizations such as the FTC or the FDA to pass judgments on cases that showed no precedence. As observed in the Lumosity lawsuit, the adaptation is transitional and should be reflected in the upcoming years.

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General Discussion

As a result of the importance of attention and executive functions, and the prominence of deficits in a number of disorders, cognitive training has an important potential value. Evidence depicts that working memory can be improved with nonpharmacological computerized interventions and the trend proposes that these interventions depict causal effects for cognition training on its subjects (Rivero, Nuñez, Pires, & Bueno, 2015). Nonetheless, concerns have been brought forward (Shinaver III, Entwistle, & Söderqvist, 2014), as it is still fairly challenging to evaluate the effect of these games in the rehabilitation process (Rivero, Nuñez, Pires, & Bueno, 2015). Moreover, there is still controversy about how to evaluate the generalization and transfer effects to patients' quotidian lives. Considerable improvements and new games in the brain training market indicate a hopeful training method for many dysfunctions. Though, the lack of blinded and independent evaluators and the frequent unsuitable use of measures and tests weakens the import of these findings (Bisoglio, Michaels, Mervis, & Ashinoff, 2014). Although we showed some improvements on general measures of intelligence and behaviour in our experimental piece, computerized cognitive training research is still in its infancy. Additional controlled studies are necessary in order to clarify the effects and stability of cognitive training and make strong and specific claims on this topic.

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