AUTONOMIC CORRELATES OF INTEGRA MINDFULNESS MARTIAL ARTS

CHANGE IN RESPIRATORY SINUS ARRHYTHMIA (RSA) AND EXECUTIVE FUNCTION IN ADOLESCENT MALES WITH LEARNING DISABILITIES

By CHRISTINA BORGES, B.A.

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AUTHOR: Christina Borges, B.A. (McMaster University)

SUPERVISOR: Dr. Louis Schmidt

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Lay Abstract

Integra Mindfulness Martial Arts [MMA] is a group treatment designed for youth with learning disabilities (LDs) and mental health challenges. Respiratory sinus arrhythmia (RSA) is a measure of variation in heart rate. Higher RSA has been linked to healthier emotion regulation, and lower RSA has been associated with anxiety and ADHD. The present study examined how MMA may increase RSA and mental flexibility in adolescent males with LD and mental health challenges (i.e., anxiety, ADHD). 19 males received the 20-week MMA intervention and 5 males did not. I found a slight increase in RSA in the MMA group, but the change was not statistically significant. The MMA group improved in their ability to independently problem solve, as well as plan and organize. MMA may positively influence biological indexes of emotion regulation and improve mental flexibility. This study helps reveal the sensitivity of RSA and validate MMA as a promising intervention.

Abstract

Learning disabilities (LDs) are often comorbid with self-regulation disorders such as ADHD and anxiety. Youth with LDs experience challenges with attention, impulsivity, and cognitive flexibility, and as a result of repeated failure, may display a pattern of experiential avoidance (EA) as a means of coping with a challenge. Integra Mindfulness Martial Arts [MMA] is a group treatment integrating mindfulness and cognitive behavioral therapy with martial arts training. While MMA has been shown to reduce externalizing behaviors and anxiety, we know little about its psychophysiological correlates. Respiratory sinus arrhythmia (RSA) is an index of heart rate variability that reflects individual differences in self-regulation, with lower levels associated with anxiety and ADHD. The sample included 26 males, aged 12 to 16 years diagnosed with LD and self-regulation challenges, enrolled in a 20-week MMA intervention (MMA; n=19), and waitlist controls (WL; n=5). Resting RSA was indexed at pre and post-intervention and the Behavior Rating Inventory of Executive Function (BRIEF) parent-report measure was collected. After intervention, I found increased resting RSA in the MMA group only. However, this change was not statistically significant, possibly due to low statistical power. Youth in the MMA group significantly improved in their ability to independently generate appropriate problem-solving strategies from pre- to post-MMA. Youth also significantly improved in their ability to anticipate future events, plan steps towards attaining goals, and appreciate main concepts when communicating information. Findings suggest that MMA may improve self-regulatory mechanisms that support appropriate emotion and behaviour regulation, suggesting there may be plasticity within these

systems. The present study provides preliminary evidence of the malleability of psychophysiological correlates of self-regulation and improvements in executive functioning in response to an MMA intervention within this population.

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General Introduction

My Master's thesis experience has aligned with my interest in the field of children's mental health. I have had the opportunity to work on two research projects that share some qualities but also allowed me to examine interventions for youth from two different perspectives.

My core research project explored Integra Mindfulness Martial Arts (MMA), an intervention designed for youth with learning disabilities and co-occurring self-regulation challenges developed and run through the Integra program at the Child Development Institute in Toronto, Ontario. This population was new to me but it was specifically interesting to learn about the deficits these youth present with that often get in the way of treating the co-occurring mental health issues, namely weaknesses in their cognitive profile and their avoidance patterns, and how many traditional therapies may not be suited for or may need to be adapted for this population. However, it was not until I went to Integra to observe and participate in the MMA intervention that I gathered a true sense of how MMA can improve the avoidance patterns, while taking into account the information processing weaknesses in these youth. The MMA session I attended emphasized change as inevitable. The sensei spoke about how everything changes – we get old, trees grow taller, and specifically, frustration and anger will pass. Being a frequent yoga practitioner myself, I felt these youth were truly learning to connect breath to their yoga poses while being mindful that the uncomfortable sensations would pass. After participating in the MMA session, my interest in the project became even more pronounced. My investigation into whether psychophysiological correlates of self-regulation are malleable

in response to MMA is important for establishing the sensitivity of these correlates, and is also crucial to validate the intervention as one that targets and improves self-regulatory capacities on a physiological level in these youth.

My second research project involved a Half-Day Intensive Program designed for youth who have severe social, emotional, and/or behavioural difficulties and who are at risk of being removed from their school placement. This program is delivered at Nelson Youth Centres in Burlington, Ontario. These youth presented with difficulties regulating behaviour and emotion which ultimately led them to struggle with disruptive behaviour in a classroom setting. Similar to the youth involved in MMA, these youth struggle academically. Additionally in both programs, learning soft skills, such as problem solving strategies and communication skills, to manage and effectively regulate their stress within a school setting may help these youth do better in school, both on a behavioural level and on an academic level. Shadowing HDI sessions highlighted the focus of recognizing emotions in yourself and in others, and ways to regulate these emotions. These lessons were executed in a creative and engaging manner for these youth, which appeared to contribute to the internalizing of the lessons. Research goals involved investigating how satisfied the youth, family, and teacher were with HDI and also how the children improved in their behaviour and in their emotion regulation at school and at home.

The two research projects are alike in that they target similar populations who present with ADHD, anxiety, and learning disabilities. Additionally, youth in both programs struggled within a learning environment and with intervention, the goal was to decrease the maladaptive coping mechanisms these youth participated in when faced with

stress and optimize outcomes. However, each evaluation examined the effectiveness of their program with a different perspective. While reports from parents, clinicians, and youth themselves are informative, identifying whether brain-behaviour relations and psychophysiological correlates may be altered in response to intervention is paramount. If research suggests these correlates index individual differences in self-regulation, it is important to assess whether there is change in these measures in response to intervention. If these measures are altered in response to intervention, this would provide evidence supporting the intervention as one that is effective in improving self-regulation on a physiological level, which correlates to improvements on a behavioural level.

Nelson Youth Centres – Evaluating Half-Day Intensive Program

From October 2013 to October 2014, I acted as a Study Consultant in the evaluation of the "Half-Day intensive Program" (HDI) at Nelson Youth Centres in Burlington, Ontario. Nelson Youth Centres is an accredited children's mental health centre that provides group based treatment programs for Halton's youth and their families. The services target children who are experiencing moderate to severe emotional, social, behavioural, and/or learning difficulties, which result in difficulties at home, school, or in the community. With a "Doing Evaluation" grant from the Ontario Centre of Excellence for Child and Youth Mental Health, we were able to evaluate the process and outcome of the most intensive program offered at the Centre.

My role as a study consultant consisted of initially meeting with the evaluation team (consisting of clinicians and support staff) before evaluation to discuss the study design and plans for evaluation. The assessment tools that were chosen for this evaluation

were either standardized or internally developed by the evaluation team. I met biweekly with this evaluation team and the representative from the funding agency to discuss progress and next steps. I scored, inputted, and analyzed the data upon collection. After I shared our results to the evaluation team, I wrote the final report, with guidance from the Executive Director. This report will be available online through the Ontario Centre for Excellence website in the coming months.

The HDI program works with youth between 9 and 13 years of age who have severe social, emotional, and/or behavioural difficulties and who are at risk of being removed from their school placement. The program is 10 weeks long and takes place one afternoon a week. Children participating in this program attend a classroom offsite to enable staff to address the internal stressors that may be producing some of the child's vulnerability and difficulties inside the school setting.

The HDI sessions are comprised of a structured milieu designed to mirror the typical school day. Youth's strengths, as identified by clinicians, parent, and teacher, are utilized to build up the necessary skills that would allow youth to become more successful in their school environment. This program provides a nonthreatening learning environment, cultivating the development and maintenance of effective social/emotional skills and learning strategies, with the goal of enabling the child to maintain their school placement and eventually be fully integrated back into their school setting. The youth's needs are addressed through individual and group interventions targeting their social and emotional capacities. Parents, teachers, and support staff are all a vital part of the

programming and provide the support needed to help the child use their new skills outside of the program setting.

This evaluation consisted of 11 clients (*M*age=10.55, *SD*=1.37; 10 male) who presented with diagnoses of ADHD, oppositional defiant disorder, anxiety, and/or learning disabilities. In order to determine if successful treatment outcomes could be attributed to the HDI program, most of the evaluation was conducted utilizing a pre/post research design. We employed a mixed methods design where we collected both qualitative and quantitative data. We were interested in whether the children's social and emotional competencies developed throughout the course of the program, by using reports from the children, clinicians, and teacher. Also of interest was the satisfaction of parents and youth with service delivery and outcome.

Our first investigation involved the delivery of the program. Demographics and presenting problems were examined to better understand the target population. We gathered information on diagnoses and other key information collected before treatment by the clinicians and parent(s). This exploration yielded five main need domains including self-regulation, social, problem-solving, self-esteem, and lastly academic. Examining program delivery, through qualitative methods, involved exploring how the program has evolved and why/how clinicians felt these modifications were working better. Our last process question involved satisfaction of service delivery where we looked at average wait times and other general questions regarding parents' satisfaction with service delivery. A majority of caregivers were satisfied with service delivery and

staff. Areas of improvement noted by parents included more involvement in choosing their child's service, and increasing convenience of the location and time of the program.

To examine outcomes of the HDI program, we first looked at whether the children had an understanding of the skills needed to be successful in school and whether they were able to implement them. With focus groups led by myself and reports from clinicians, we explored common reported themes and found that children did have an understanding of the skills needed to be successful in school and seemed to be using these new skills in the treatment group. Also of interest was whether the child could function effectively in the school setting. With a pre/post design, self-reports of the child's social functioning in the school setting suggested improvement in this domain, as assessed through the Social Skills Improvement System (SSIS; Gresham & Elliot, 2008). Additionally, parents and clinicians believed the children were behaving better at school, as assessed through internally developed tools. However, these positive findings were not manifested objectively as increased academic performance, as assessed through academic grades. Teachers had mixed opinion on whether the children had improved in their socio-emotional skills, and importantly, did not see any improvements in academic grades. We believe that if the children have more time to practice their newly learned skills, teachers would observe an increase in academic grades. The evaluation team suggested that after these youth practice new problem solving strategies, they would be better able to generalize these skills in new situations such as while completing an academic task within the classroom.

These results were shared with stakeholders and presented via information tables set up at parent groups and community fairs. Importantly, this use of data and evaluations gave clinicians and support staff clarity on the impact of HDI on the target population. With this evaluation, Nelson Youth Centres also learned the importance of evaluating programs and hopes to implement evaluation into other programs delivered at the Centre.

Introduction

Learning Disabilities (LDs)

Learning Disabilities (LDs) are neurobiological disorders that affect the acquisition, organization, retention, understanding, or use of verbal and/or nonverbal information (LDAC, 2002; Silver et al., 2008). LDs are distinct from intellectual disabilities in that youth with LDs have average to above average levels of intelligence. In individuals with LDs, the presence of information processing challenges in areas such as expressive and receptive language, visual-spatial processing, memory and attention, and executive functions (EFs) negatively impact their ability to succeed academically. As such, youth with LDs exhibit significantly lower levels of academic ability in one or more areas including math, reading, and writing. Verbal LDs are associated with atypical functioning in the areas of word decoding or identification, reading comprehension, calculation, mathematical reasoning, spelling, and/or written expression (Silver et al., 2008). LDs range in severity and may interfere with academic performance in written or oral language, reading, and/or mathematics. On average, students with an LD are 3.4 years behind their enrolled grade level in reading and 3.2 years behind in math (LDAC, 2002). Nonverbal LDs are different than verbal LDs in that their deficits do not impact

their verbal skills such as reading and writing, and are often more difficult to identify. Youth with nonverbal LDs have strong reading and writing abilities, but may present with a lack of motor coordination, common social skills and the ability to interpret nonverbal communication.

LDs are thought to be due to genetic and/or neurobiological factors or injury, which alters brain structure and functioning. Heredity is a major risk factor, as LDs seem to occur at higher rates within members of the same family than in the general population (Cortiella, 2011; LDAC, 2002). This work suggests that genetics play an important role in the development of brain regions and circuits that regulate the deficits associated with LDs (Chase, Rosen, & Sherman, 1996; Duane, 1999; Gayán et al., 1999; Petryshen, Kaplan, Liu, & Field, 2000; Regehr & Kaplan, 1988). However, no single gene is responsible and it may be the combination of risk genes that contribute to abnormal brain development and function (Gilger & Kaplan, 2001). While many studies have attempted to elucidate specific brain structures and functions affected in individuals with LDs, research has not identified a clear link between particular brain regions and the development of an LD. Gilger and Kaplan (2001) suggest that individuals with LDs likely have multiple anomalies, some of which are subtle and others of which can be more readily identified at the phenotypic level. Therefore, symptoms exhibited by individuals with LDs (e.g., reading, mathematics, spelling, motor, attentional, or some combination) will depend on the relative amount of abnormal development in primary ability areas of the brain (e.g., language areas or connections in, around, or to and from the temporal lobe) and which of the many other brain areas are also affected (Gilger & Kaplan, 2001).

LDs may also be contributed to by environmental influences during pre-natal and early post-natal development. Colletti (1979) found that children with LDs had a higher number of pregnancy and birth complications than controls. Other proposed risk factors for LD include maternal drug and alcohol use during pregnancy, low birth weight, or prematurity and prolonged labor (LDAC, 2002). Environmental factors most likely act in combination with genes to place an individual at risk for LDs (Gilger & Kaplan, 2001).

LDs are not due primarily to visual, hearing or motor disabilities, socio-economic factors, cultural or linguistic differences, lack of motivation or ineffective teaching, although these factors may further complicate the challenges faced by individuals with LDs (Cortiella, 2011; LDAC, 2002). People living in poverty are more likely to report having LDs (Cortiella, 2011). This may be a result of poor nutrition, ingested and environmental toxins (e.g., lead) or other risk factors during early and critical stages of development. LDs affect Caucasians and African-Americans about equally across all ages.

LDs are the most common form of disability for children aged 5 to 14 years, and affect over three million Canadians (LDAC, 2002). Data for Ontario from the National Longitudinal Survey of Children and Youth (NLSCY) revealed 6.2% of children aged 6 to 15 were reported by parents/guardians to have a learning disability (PACFOLD, 2007). Rates of prevalence are similar in the United States where in 2009, 5% of all students in public schools were identified as having LDs (Cortiella, 2011). Males are more likely to have identified LDs than females (Cortiella, 2011).

The ways in which LDs manifest within an individual may depend on the interaction between their strengths and needs and the demands of their environment. Additionally, these factors may vary across development. Accordingly, LDs are associated with significant suffering for individuals and their families, and as well as increased health care and societal costs. Crawford (2002) estimate the cost of an LD from birth to retirement is $1.982 million per person. Assuming a lifetime prevalence of 5%, the cost of LDs in Canada is about $3.1 billion from birth to retirement for individuals with LD, their families and to private programs in Canada (Crawford, 2002). In educational settings, the cost of a student with an LD is 1.6 times that of other students (LDAC, 2002).

LD: Comorbid Disorders

While academic impairments are often the focus of attention in youth with LDs, negative outcomes frequently extend beyond the classroom, impacting on mental health (Milligan, Badali, & Spiroiu, 2015). Youth with LDs are at increased risk of having co-occurring mental health problems, as well as additional social, emotional, and behavioural concerns. Ontario data from the National Longitudinal Survey of Children and Youth (NLSCY) found that 14.7% of parents of children with LDs said that their child had been diagnosed with emotional or psychological difficulties, while parents of children without disabilities reported rates of just 1% (PACFOLD, 2007). Similarly, in a sample of 949 children aged 6 to 16 years, Mayes and Calhoun (2006) found LDs were often co-morbid with ADHD, autism, oppositional defiant disorder, anxiety, and/or depression. Among the most common comorbid disorders is ADHD, with 71% of those with LD being affected.

There are information processing weaknesses common in both LDs and psychological disorders (Barkley 2002, Bauminger, Schorr Edelsztein,& Morash, 2005), which may contribute to the high rate of comorbidity. For example, weaknesses in EFs (e.g., inhibition, cognitive flexibility, working memory, organization, and planning) commonly present in youth with LDs and ADHD (Mattison & Mayes 2010; Pennington & Ozonoff, 1996). Research also suggests that students with LD experience more anxiety than their non-LD peers (Huntington & Bender, 1993; Margalit & Raviv, 1984; Rodriguez & Routh, 1989; Stein & Hoover, 1989).

Behavioural challenges are common among youth with LD. Schachter, Pless, and Bruck (1991) found that 43% of youth with learning disabilities had behaviour problems, according to the Child Behavior Checklist (CBCL; Achenbach & Edelbrock, 1981). Similarly, Cortiella (2011) reported that one-third of youth with LD are suspended or expelled from school at some point in their school years. The school dropout rate of students with LD is higher than that of their peers (Sinclair, Christenson, Evelo, & Hurley, 1998), leaving them at even greater risk for social and economic disadvantages (Morrison & Cosden, 1997). A large body of research also suggests significant differences between adolescents with and without LDs in terms of substance use disorders (Beitchman, Wilson, Douglas, Young, & Adlaf, 2001; Cosden, 2001; McNamara, Vervaeke, & Willoughby, 2008; Molina & Pelham, 2001; Weinberg, 2001), and the use of nicotine, alcohol, and other recreational drugs (Maag, Irvin, Reid, & Vasa, 1994; McNamara et al., 2008; Weinberg, 2001). Adolescents with LD have significantly higher rates of delinquent behaviour (McNamara et al., 2008), with their likelihood of arrest and

adjudication also higher than adolescents without LD (Keilitz & Dunivant, 1986). A disproportionately high rate of incarcerated juveniles (over 14%) are identified with LD (Cortiella, 2011). Overall, adolescents with LDs report higher levels of externalizing behaviours, such as aggression and risk-taking (McNamara et al., 2008, McNamara & Willoughby, 2010). A poor understanding of one's disability, a lack of skills for developing peer relationships, and the need for prolonged family support have been identified as risk factors for these behaviours (Cosden, 2001). Perhaps this evidence amounts to a characteristic feature of adolescents with LDs, which may be an inability to comprehend social cues and use feedback to adjust their behaviour.

Youth with LDs often struggle within social situations and thus, experience feelings of loneliness. A meta-analysis conducted by Kavale and Forness (1996) suggested that 75% of students with LDs manifest social skills deficits that distinguish them from their non-LD peers. Children with LD are more likely to be socially rejected (Greenham, 1999), neglected (Wiener, Harris, & Shirer, 1990), victimized by peers (Mishna, 2003), are less popular (Wiener, Harris, & Shirer, 1990), and have a more impoverished peer network overall (Al-Yagon, 2012). The loneliness that children with LD experience is particularly prevalent in the adolescent period (see Goossens, 2006, for a review). Wiener and Schneider (2002) found that compared to children without LD, boys with LD had fewer and younger friends, and that these friends frequently also had learning problems. Boys with LD often have unstable friendships, higher levels of conflict and lower levels of validation within their friendships (Wiener & Schneider, 2002). Research suggests that these negative social outcomes may be worse for youth

who have both LDs and comorbid psychiatric diagnoses. Students with LD and other psychiatric disorders such as ADHD, oppositional defiant/conduct disorder, anxiety, and/or depression report a significantly higher amount of peer victimization than children without a comorbid psychiatric condition (Baumeister, Storch, & Geffken, 2007; McNamara, Willoughby, & Chalmers, 2005).

These comorbidities also cost individuals with LD, their families, and society. Smith and Smith (2010) postulate that improving a child's mental health has been found to result in lifetime savings of $140,000. This report also estimated the lifetime economic cost of childhood mental disorders in Canada to be $200 billion. Hence, LDs and their associated mental health comorbidities can have an economic impact on all Canadians.

LD: Processing of Emotional Information

The ability to interpret emotional cues is important for healthy adjustment within a school environment as well as while interacting with peers outside of school. This ability would be especially helpful for youth with LDs who struggle with social, emotional, and behavioural difficulties. However, children with LD have been found to display consistent difficulties in understanding complex emotions (embarrassment, pride, guilt, loneliness), as well as in comprehending higher emotional capabilities, such as understanding that two conflicting emotions (e.g., love and hate) can be simultaneously experienced (Bauminger et al., 2005). The ability to understand complex emotions or mixed or hidden emotions plays an important role in efficient and effective peer interaction. Compared to their peers, children and adolescents with LD seem to be less accurate at recognizing emotions from facial expressions (Holder & Kirkpatrick, 1991;

Most & Greenbank, 2000), which may contribute to their relatively lower social status. On the whole, research clearly demonstrates that adolescents with LD manifest more socioemotional difficulties than their typically developing peers.

Saarni (1999) has also proposed a list of the many skills that are essential to the development of emotional competence. Along with the ability to recognize others' emotional states, an awareness of one's own emotional states and the ability to cope with emotionally distressing situations is also postulated as important for the development of emotional competence. Bauminger and Kimhi-Kind (2008) found that children with LD had worse emotion regulation than children without LD, as assessed by the Children's Self-Control Scale (CSC; Rosenbaum & Ronen, 1991). Youth with LD also experience lower positive affect and higher negative affect than their non-LD peers (Lackaye & Margalit 2006; Maag & Reid 2006). These factors may contribute to the higher risk seen in youth with LD for emotional distress, suicide attempts, and violence (Svetaz, Ireland, & Blum, 2000).

Current Treatments for LD

Youth with LDs can make use of various therapeutic approaches aimed at improving their social, emotional, and behavioural difficulties. With therapy, coping skills and compensatory strategies may be developed to prevent and better manage their difficulties with friendships, school, self-esteem, and daily life. Past research has examined the effectiveness of pharmacological treatment specifically in youth with LD comorbid with ADHD, and non-pharmacologic therapeutic methods such as social skills training. Pharmacological treatment has been found to be superior to non-

pharmacological interventions for some domains and no differences between treatment modalities have been found for other domains, suggesting combined treatment may give youth with LD and ADHD the best chance to succeed. Research on social skills training has not provided promising results; however, it may be the case that there are barriers to providing effective treatment for youth with LD that need to be addressed.

Current treatments for LD: Pharmacological treatment. Individuals with LDs and particularly those with comorbid LD/ADHD have received psychotropic interventions for many years. With ADHD being a common comorbid disorder in youth with LDs, examining how ADHD symptoms may be alternatively improved is important when aiming to treat these symptoms, as well as the other comorbid mental health challenges that often present in these youth. Almost three decades ago, Barkley and Cunningham (1978) examined the effects of stimulant medication on academic performance in children with ADHD and concluded the major effect of stimulants appears to be an improvement in classroom manageability, rather than academic performance. Since this review, the literature regarding the effectiveness of medications on learning performance and their side effects has been inconsistent (Gadow, 1983; Swanson, Cantwell, Lerner, McBurnett, & Hanna, 1991).

A more recent meta-analysis by Van der Oord, Prins, Oosterlaan, and Emmelkamp (2008) sought to explore how stimulant medication (methylphenidate), psychosocial treatments (behavioural or cognitive-behavioural), or the combination may improve ADHD symptoms and related outcomes such as oppositional defiant/conduct problems, social behaviour, and academic functioning in school-aged children with

ADHD. This meta-analysis found that both methylphenidate treatment and behavioural/cognitive-behavioural treatments are effective in reducing ADHD symptoms, except for academic functioning where no treatment was found to be effective (Van de Oord et al., 2008). For ADHD symptoms however, both methylphenidate and combined treatments were more effective than behavioural/cognitive-behavioural treatments alone. All three treatment modalities were found to be equally effective in improving oppositional defiant/conduct problems, and social behaviour. While these findings suggest methylphenidate treatment may be superior to psychosocial treatments for ADHD symptoms specifically, it may be the case that combined treatment may give youth the best chance to succeed overall. However, this may only apply to individuals who are not sensitive to the side effects common to methylphenidate use. Schachter, Pham, King, Langford, and Moher (2001) found that 1 in 4 youth treated with stimulants reported decreased appetite, and 1 in 7 reported insomnia. Additionally, improvements have been found to diminish when medication is discontinued (Abikoff et al., 2004a,b). Despite these disadvantages to methylphenidate treatment, perhaps it is the case that some youth with LD/ADHD may respond best to this form of treatment or a combination of methylphenidate and behavioural or cognitive-behavioural interventions.

The use of psychotropic medication to treat behaviour problems in youth with LD raises a number of issues. Gadow (1986) proposed several problems associated with the use of medication in school-aged children, including the administration and monitoring of medication in school; establishing communication between parents, teachers, and physicians; and training teachers and school staff to be competent and confident

evaluators of treatment effects. Epstein, Singh, Luebke, and Stout (1991) sought to investigate these potential complications and found that less than 15% of teachers indicated that their professional pre-service training had provided them with sufficient information on the use of medication for children with behaviour problems. This result suggests that additional training on drug interventions is important for educators if psychotropic medication is to be administered to school-aged children.

Current treatments for LD: Social skills training. The high prevalence of social skills deficits in children with LD highlights the need to identify effective interventions designed to teach social skills to these children. Social skill commonly taught with these interventions include starting a conversation, asking a question, and learning how to listen, apologize, and deal with frustration, etc. However, evidence seems to suggest that few existing interventions successfully improve social skills in children with LD. McIntosh, Vaughn, and Zaragoza (1991) reviewed 22 studies of social interventions for students with LD and found that only 14 reported intervention effects. Importantly, out of the five studies that directly targeted social acceptance as identified by peer ratings, only two reported significant increases. In a more recent meta-analysis by Kavale and Mostert (2004) found social skills interventions improved ability to interpret social cues and provide appropriate responses, but the training did not foster greater interaction and these youth still remained relatively isolated from peers. This investigation found that only about 58% of youth with LDs showed positive effects from social skills training, suggesting the interventions are no more than modestly effective (Kavale & Mostert,

2004). This suggests there is inconclusive evidence of the efficacy of social skills training.

It may be the case that this type of training or teaching can unintentionally reinforce the dependence upon adults of youth with LD (Mishna, Kaiman, Little, & Tarshish, 1994). Adolescents with LD are often dependent upon and compliant with adults, and social skills training may further complicate this dependence. Motivation and sense of self-efficacy can diminish, impacting their ability to foster social relationships without adult guidance. Therefore, it may be beneficial that the child learns social skills from interactions with peers, as opposed to adults. Additionally, these social skills interventions may not be matched to the reasons these youth fail to perform social skills. Maag (2005) posits that these youth with LDs lack requisite behavioural skills and are unable to sequence such skills into a successful peer interaction, and importantly select behaviours automatically rather than consciously. This suggests that these youth with LDs may benefit from learning to stay present and conscious of their behaviours, enabling them to better interact with others.

Barriers to Providing Mental Health Treatment

Providing effective mental health treatment for youth with LDs is often complicated by two factors: (1) the weaknesses present in their cognitive profile and (2) their pattern of experiential avoidance as a result of repeated failure.

Treatment barriers: Cognitive profile. Studies have consistently demonstrated executive function (EF) deficits in individuals with LDs comorbid with ADHD. Research suggests a commonality of EF deficits within both ADHD and LD. Interestingly,

Seidman, Biederman, Monuteaux, Doyle, and Faraone (2001) found that boys with co-occurring ADHD and LD performed worse on EF measures, including the Stroop Task which measures inhibition and cognitive flexibility, compared to boys with ADHD and no LD. Mattison and Mayes (2010) found that children with LD/ADHD scored lower on Wechsler Intelligence Scale for Children (WISC) indices of working memory and processing speed, as well as on the EF composite and visual-motor integration (VMI). Children with ADHD with EF deficits have also been found to have significantly worse academic dysfunction, including increased prevalence of LDs, compared to ADHD children without such deficits (Biederman et al., 2004). Essentially, the addition of LD to ADHD appears to be associated with worse executive dysfunction.

Reed (1997) posits that individuals with LD have been one of the most ignored groups in terms of mental health services and psychological research into therapeutic techniques. Few treatments have been modified for youth with LDs or other information processing difficulties (Moree & Davis 2010). Core therapeutic approaches, such as reflecting on or talking about experiences, setting goals and developing problem-solving plans, remembering and utilizing coping strategies, and generalizing information or strategies to new settings can be adversely impacted by information processing weaknesses (Cosden et al. 2009). These central methods of therapy may be difficult for individuals with LD due to their challenges in EF (e.g., planning and organizing), memory, attention, language and communication abilities, and information processing speed. As such, many traditional evidence-based therapies, such as problem-solving

skills training, need to be tailored or altered to meet the unique learning profiles of individuals with LD in order to be optimally effective.

Treatment barriers: Experiential avoidance. A review by Arthur (2003) revealed evidence to suggest that significantly higher levels of emotional problems and disturbances in individuals with LDs. Specifically, youth with LDs may experience feelings of low self-esteem, failure, shame, and self-doubt associated with the school challenges they have experienced (Arthur, 2003; Mishna & Muskat, 2004). These individuals are often overwhelmed by feelings of sadness, loss, confusion, helplessness, incompetence, inadequacy, anxious anticipation and fear of failure and humiliation. Youth with LDs may also experience higher levels of fearfulness (Ramirez & Kratochwill, 1997). These lived experiences can lead to specific patterns of emotion regulation, which in turn can complicate treatment.

To cope with these strong negative emotions, many youth with LDs may avoid interactions, activities, thoughts, and emotions associated with failure or distress (Milligan et al., 2015). As such, these youth avoid challenging work, which can include tests and assignments in school and addressing their mental health issues. Avoidance can be accomplished by either withdrawing from the stressful situation or engaging in problem behaviours that enable them to avoid or even distract them from the experience of distress (Ducharme & Harris, 2005). For youth with LDs, avoidance behaviours may include avoiding social interactions or school altogether, as these encounters may have previous been associated with distress and/or frustration. This pattern of behaviour is consistent with the paradox of experiential avoidance (EA). Hayes, Wilson, Gifford,

Follette, and Strosahl (1996) describe EA as an unwillingness to remain in contact with aversive private experiences, such as bodily sensations, emotions, thoughts, memories, and behavioural predispositions.

EA is thought to be a putative pathological process that is critical to the development and maintenance of psychopathology (Chawla & Ostafin, 2007; Hayes, Strosahl, & Wilson, 1999). In clinical and non-clinical samples, EA has been strongly correlated with measures of general psychopathology (Hayes et al., 2004) and specific measures of anxiety and depression (Forsyth, Parker, & Finlay, 2003; Marx & Sloan, 2005; Roemer, Salters, Raffa, & Orsillo, 2005; Tull, Gratz, Salters, & Roemer, 2004). Kashdan, Barrios, Forsyth, and Steger (2006) suggest that EA is a general psychological vulnerability to anxiety-related pathology and disruptions in the elements of satisfying and meaningful living.

The paradox of EA is that attempting to hide or inhibit unpleasant thoughts, feelings, and bodily sensations serves to increase the frequency and distress of these same experiences in the long term (Gross, 1998, 2002). This tendency to engage in behavioural avoidance strategies in response to distress is called *avoidance coping* and is associated with negative psychological outcomes (Penley et al., 2002).

The phenomenon of EA is consistent with Skinner's theory of operant conditioning. These avoidance behaviours are maintained and strengthened through the process of negative reinforcement, where a response is strengthened by the removal of an aversive stimulus (Skinner, Ferster, & Ferster, 1997). Avoiding aversive private experiences (thoughts, emotions, etc) and events (social interactions, physical activity, or

even school participation) can provide short-term relief of discomfort, and through negative reinforcement these patterns are strengthened and likely to occur again.

The approach of avoiding aversive private experiences has been supported by a large body of literature that propose similar strategies such as thought suppression, emotional suppression, and avoidance coping. Cognitive strategies such as thought suppression involve suppressing unwanted thoughts and controlling them through means such as distraction and worry, which has been shown to lead to a paradoxical increase in the occurrence of the target thoughts (Wenzlaff & Wegner, 2000). Emotional suppression involves avoiding affective experiences has also been associated with poor psychological health outcomes (Gross & Levenson, 1993). Avoidance coping is the tendency to engage in behavioural avoidance strategies and has also been associated with negative psychological outcomes (Penley, Tomaka, & Wiebe, 2002). While each of these strategies have a unique label, they may generally characterize a form of EA but rather represent specific methods by which action is taken to alter aversive private experiences.

The literature suggests each avoidance strategy ultimately serves to maintain maladaptive coping. Thus, youth with LDs and self-regulation challenges require treatments that will help them stay present with the unpleasantness so that they can learn and develop new ways of coping, instead of using avoidance strategies. These youth often avoid social interactions that often end in rejection or the demanding school environment that is often associated with failure, and thus these youth can benefit from learning to stay present and accepting the challenges they are presented with. Psychological acceptance, the opposite of EA, would allow these youth to alter the impact of emotions and

cognitions by shifting their view of them, rather than by attempting to hide from all forms of unpleasantness.

Integra MMA: An Evidence-Informed Group Intervention for LD

Integra Mindfulness Martial Arts (MMA) intervention is an evidence-informed group treatment designed for adolescents aged 12 to 18 with LDs and co-occurring self-regulation difficulties (Integra & Badali, 2002). MMA was developed at Integra Foundation in Toronto, Ontario. MMA integrates mindfulness, behaviour modification and cognitive therapy with yoga and mixed martial arts training. The goal of MMA is to improve youth's self-awareness so that they can learn and practice more adaptive coping strategies that enable them to stay present with and better handle the challenges they face. The following literature and discussion will highlight the components of MMA.

MMA: Group therapy. Group therapy has been noted as beneficial for adolescents, especially those who have deficits in social skills and low self-esteem (Scheidlinger & Aronson, 1991). Group therapy provides both a social interaction which can lessen feelings of isolation and facilitates increased self-esteem through being accepted by the group and by helping others. For these reasons, group treatments may be of particular use to adolescents with LDs; however, this population is often not offered group therapy (Mishna, Kaiman, & Tarshish, 1994; Mishna & Muskat, 2004). Deficits in their cognitive profile may negatively impact participation within group treatment; however, despite the required modifications, these authors suggest youth with LDs may still benefit from therapy in a group setting. Specific advantages of group therapy for youth with LDs include the opportunity to be surrounded by similar peers who are

struggling with similar problems and to discuss their LD and its influence on their everyday lives (Mishna & Muskat, 2004).

Adolescents with LDs often have particular difficulty thinking and talking about their feelings (O'Connor, 2001). To help overcome these struggles, Coche and Fisher (1989) have suggested peer groups allow for discussions of emotions. Additionally, Pickar (1988) proposes that "for a child who is forever misperceiving the social cues of others or has little sense of the impact of his/her behaviour on others, the group provides a supportive reality-testing environment where such difficulties can be exposed, confronted, and worked on, with the group leader attempting to minimize the anxiety that might typically result from fear of ridicule or rejection" (p. 765-766). This is especially important for youth with LDs who may cope with challenges through EA as this reality testing environment forces youth to stay present with challenges encountered when in a group setting, which may work to reduce the anticipation and fears of rejection and ultimately lead to a reduction in avoidance behaviours. In short, the literature points to group therapy as a promising treatment modality for adolescents with LDs and related social and emotional problems. This therapeutic modality provides a peer group that is essential for social and emotional development in this clinical population, but yet these types of interventions seem to be lacking in the literature.

MMA: Mindfulness. Mindfulness is a way of directing attention that originated in Eastern meditation and is entrenched in ancient Buddhist and yoga practices. Kabat-Zinn (1994) described mindfulness as ''paying attention in a particular way: on purpose, in the present moment, and nonjudgmentally'' (p. 4). Mindfulness techniques serve to

enhance awareness of the present moment and to increase nonjudgmental self-observation. Phenomena that enter an individual's awareness during mindfulness practice such as perceptions, cognitions, emotions, or sensations are observed carefully but are not evaluated as good or bad, true or false, healthy or sick, or important or trivial (Marlatt & Kristeller, 1999). Instead, in mindfulness, the individual would simply observe and accept the various forms of sensations as they arise.

Cognitive and behavioural psychotherapies do not solely focus on acceptance of all feelings. Behavioural therapies focus on changing behaviours (and subsequently feelings), and cognitive therapies focus on changing one's perceptions of situations. While these commonly applied psychotherapies have been found to be effective in a wide range of populations such as youth with anxiety (Ishikawa, Okajima, Matsuoka, & Sakano, 2007), depression (Hetrick et al., 2014), delinquency and conduct problems (Weisz, Jensen-Doss, & Hawley, 2006), mindfulness has a more direct focus on acceptance without an emphasis on change. In fact, EA may be targeted with mindfulness interventions, as mindfulness is designed to counter this avoidance by encouraging deliberate, nonjudgmental contact with cognitions, feelings, or sensations that arise (Hayes &Wilson, 2003). Many modern therapies now incorporate this idea of mindfulness and psychological acceptance.

The Mindfulness-Based Stress Reduction (MBSR) program, formerly referred to as the stress reduction and relaxation program (SR-RP; Kabat-Zinn, 1982, 1990), was the first program to apply mindfulness ideas and practices into clinical practice. This program was initially designed for people with pain and stress-related disorders that were difficult

to treat using traditional approaches in hospital settings. MBSR uses a combination of mindfulness meditation, body awareness, and yoga to help people become more mindful. Mindfulness-Based Cognitive Therapy (MBCT; Segal, Williams, & Teasdale, 2002) also incorporates the fundamentals of MBSR. MBCT incorporates elements of cognitive therapy that facilitate a disconnected view of one's thoughts including statements such as "thoughts are not facts" and "I am not my thoughts", and was designed to prevent depressive relapses. This attitude toward depression-related cognitions is believed to prevent the escalation of negative thoughts into ruminative patterns (Teasdale, Segal, & Williams, 1995). Other types of interventions incorporate mindfulness training into their protocols, such as Dialectical Behaviour Therapy (DBT; Linehan, 1993a, 1993b) and Acceptance and Commitment Therapy (ACT; Hayes, Strosahl, & Wilson, 1999).

Baer (2003) outlined the mechanisms by which mindfulness may act to alter detrimental patterns of behaviour. The first mechanism is exposure, which suggests that the ability to observe pain sensations nonjudgmentally can reduce the distress associated with pain. Similarly, Kabat-Zinn et al. (1992) proposed that deliberate and nonjudgmental observation of anxiety-related sensations, without attempts to escape them, can lead to decreased emotional reactivity. For youth with LDs and comorbid mental health challenges, this could mean observing the sensations of anxiety, anger, frustration, etc. as they come. Cognitive change is also a core component of mindfulness. Nonjudgmental observation of anxiety-related thoughts may lead to the understanding that they are merely just thoughts, rather than reflections of reality, and do not require avoidant behaviour (Kabat-Zinn, 1990). Self-observation of emotions, sensations, etc. promotes the

use of a range of coping skills, resulting in a more adaptive management of such emotions, sensations, etc. Acceptance involves "experiencing events fully and without defense, as they are" (Hayes, 1994, p. 30). Acceptance becomes essential when encountering unpleasant symptoms, such as anxiety or panic attacks where accepting them can be beneficial, instead of striving to escape or avoid them. As an example, youth with LDs struggle with homework as it is a difficult task for them and it may take longer to complete than it does for their peers, especially for those with verbal LDs. These youth may experience frustration with their efforts and additionally, their academic marks often may not reflect their level of effort. It is possible that if youth with LDs work towards accepting these struggles, they would learn to view them, as well as feelings of frustration, as temporary and not dangerous. This mindset could enable youth to recognize these feelings as unpleasant but brief experiences to be tolerated, rather than fearsome and dangerous experiences to be avoided. Additionally, although relaxation may not be a primary reason for engaging in mindfulness practices, the mindfulness exercises may lead to increased physical and mental relaxation, which may assist with the management of stress-related disorders such as anxiety. Teaching nonjudgmental observation of current conditions such as racing thoughts, physiological arousal (i.e., increased heart rate), and other phenomenon incompatible with relaxation may contribute to this increased relaxation.

Mindfulness training is typically delivered in a group setting. A group setting may best facilitate the training of mindfulness practice because discussion of what is being taught may be increased when fellow group members can share different experiences and

comments. Semple, Lee, and Miller (2006) suggest group members can also help the process by aiding in the teaching and supporting of others. For youth, this group setting can also facilitate the development of friendships, especially when they present with social skill deficits.

The literature suggests mindfulness-based therapies (MBTs) can be beneficial for a variety of adult psychological problems. For example, MBTs has been shown to be an effective intervention for relapse prevention in patients with previous depressive episodes (Piet & Hougaard, 2011; Ma & Teasdale, 2004). Mindfulness interventions have led to reductions in other conditions such as pain (Kabat-Zinn, 1982), stress (Kabat- Zinn et al., 1992), disordered eating (Kristeller & Hallett, 1999), and borderline personality disorder (Linehan et al., 2006). A review by Hofmann, Sawyer, Witt, and Oh (2010) supports the use of MBTs for anxiety and depression in clinical populations. It is believed that learning to respond to stress more reflectively, rather than reflexively, can counter EA strategies that are believed to be critical in the development and maintenance of emotional disorders. This is particularly relevant to youth with LDs. Additionally, Ganguli (1988) investigated the relation between mindfulness meditation and social skills and found that adults who participated in the meditation indicated improvements in their interpersonal relations, suggesting meditation can positively influence social functioning.

In addition to the research on the impact of mindfulness on psychosocial problems in adulthood, mindfulness practices have also been linked to positive changes in the brain. Davidson (1993) proposed a model of resting frontal asymmetry, which suggests that the left frontal regions may be more active during the experience of approach-related (i.e.

positive) emotions and the right frontal regions may be more active during the experience of withdrawal-related (i.e. negative) emotions. In a study involving a mindfulness meditation training program that was 8 weeks in length, Davidson et al. (2003) observed, for the first time, significant increases in left-sided activation after training in the meditators compared to wait-list controls. This brain pattern of increased positive affect after meditation suggests mindfulness may have physiological effects.

Research investigating the benefits of MBTs in youth is starting to accumulate. Mindfulness training has been found to be effective in a variety of externalizing disorders (Bogels, Hoogstad, van Dun, de Schutter, & Restifo, 2007). Specifically, mindfulness training has led to reductions in aggressive behaviour in adolescents (Singh et al., 2007). Practicing mindfulness may help the adolescent focus and attend to the conditions, both internal and external, that give rise to these maladaptive behaviours. This purposeful attention can foster the development of other coping strategies, and lead to reductions in reflexive, aggressive actions. Additionally after mindfulness training, investigations involving youth have found reductions in anxiety symptoms (Semple, Lee, Rosa, & Miller, 2010; Semple, Reid, & Miller 2005), and improvements in behavioural regulation, meta-cognition, and executive control (Flook et al., 2010), suggesting mindfulness-based approaches may improve adjustment by enhancing self-regulatory capacities. The research in this area helps demonstrate the promise of MBTs as effective interventions for a variety of detrimental psychological conditions in youth (see Hofmann et al., 2010; Zoogman, Goldberg, Hoyt, & Miller, 2014).

MMA is a mindfulness-based program that has been designed specifically for youth with LDs and emotional and behavioural self-regulation challenges (Haydicky, Wiener, Badali, Milligan, & Ducharme, 2012). MMA is tailored for youth with LDs, as it aims to counteract the avoidance patterns that are common in these youth with its core emphasis on mindfulness. Importantly, MMA is modified to take into account the deficits that often present in the cognitive profile of these youth, as the group solely consists of similar youth. However, we know of only one peer-reviewed study examining effects of mindfulness meditation training among adolescents with LDs. Beauchemin, Hutchins, & Patterson (2008) introduced mindfulness meditation into the classroom of a private residential school specializing in serving students with a primary diagnosis of LD. The mindfulness meditation sessions took place for 5 to 10 minutes at the beginning of each class period 5 days per week for 5 consecutive weeks. The main goals of the mindfulness meditation were to intentionally observe thoughts or feelings and pay attention nonjudgmentally. Beauchemin et al. (2008) were primarily interested in how mindfulness meditation may impact anxiety, social functioning, and academic performance after 5 weeks of training and found reductions in anxiety, and improvements in social skills and academic functioning (Beauchemin et al., 2008). Furthermore, mindfulness therapies have been found to be effective for youth with similar information processing challenges, such as ADHD (van der Oord, Bogels, & Peijnenburg, 2012; van de Weijer-Bergsma, Formsma, de Bruin, & Bogels, 2012).

MMA: Cognitive therapy. Cognitive therapy is integrated into MMA sessions to address cognitions that negative events or qualities are fixed and unchanging. This is

important because a youth's mindset can impact their approach to academic and social challenges (Yeager & Dweck, 2012). Students who consider abilities to be qualities that can be developed and enhanced, as opposed to qualities that are stable, tend to show higher achievement across challenging school transitions. This research suggests that resiliency in the face of rigorous learning opportunities can be developed if youth are redirected to view abilities as able to be developed over time with effort, good strategies, and help from others, rather than as fixed qualities (Yeager & Dweck, 2012). Likewise, a mindset that personality traits are fixed can lead adolescents to interpret peer victimization or exclusion as something that will never change (Yeager, Trzesniewski, Tirri, Nokelainen, & Dweck, 2011).

Detecting and challenging the negative self-statements that present in these youth is another important way cognitive therapy is incorporated into MMA. The association between negative self-talk and greater levels of anxiety has consistently been found in various samples and developmental periods. Kendall and Treadwell (2007) found that negative self-talk moderates the impact of treatment on anxiety in youth. Specifically, changes in anxious self-statements mediated treatment gains in children with anxiety disorders.

With MMA, cognitive change is incorporated with the goal of challenging negative patterns of thinking. Once youth become present with their patterns of thinking through mindfulness practices, they may work towards challenging these patterns. Baer (2003) suggests cognitive change can result from viewing one's thoughts as temporary phenomena without meaning, rather than as necessarily accurate reflections of reality or

worthiness. Using research on the Growth Mindset, a construct coined by Dweck (2006), it is beneficial for these youth to believe in their ability to change situations. In this Growth Mindset, the overarching belief is that abilities can be developed through dedication and hard work. This view fosters learning and a resilience that is essential for overcoming challenges. Individuals with a growth mindset do not mind or fear failure as much because they realize their performance can be improved and learning comes from failure. On the contrary, individuals with a fixed-mindset dread failure because it is a negative statement on their basic abilities. The cognitive therapy aspect of MMA is particularly important to the development of mindful self-talk, as it aims at challenging the patterns of negative self-talk that are often present in youth with LDs and co-occurring self-regulation challenges. Mindful self-talk can help these youth with accepting challenges, staying present, and regulating associated emotions. This training in self-directed attention involves sustained contact with sensations, thoughts, and emotions, which can result in the desensitization of previously conditioned responses and the reduction of avoidance behaviour.

MMA: Exercise, yoga, & martial arts. Physical exercise has been found to produce positive psychological benefits in adults with anxiety, depression, cognition, socialization, and more (see Hughes, 1984 for a review). The effect of physical activity on mental health in adolescents has received significantly less attention than among adult populations (Paluska & Schwenk, 2000). In youth, some research has suggested physical exercise improves cognitive and academic performance (Sibley & Etnier, 2003), as well as social self-esteem (Telles, Singh, Bhardwaj, Kumar, & Balkrishna, 2013). Physical

exercise is also associated with a positive effect on depression, anxiety, mood, and self-esteem in children and adolescents (Floriani & Kennedy, 2008; Ortega, Ruiz, Castillo, & Sjöström, 2008).

In males with LDs, a 20-week aerobic exercise program was found to improve self-concept (MacMahon & Gross, 1987). Involvement in physical exercise may be especially important for youth with LDs who possess strong avoidance patterns. Working towards improving fitness in a motivating environment with others going through the same struggles can be beneficial for these youth with LDs who may be facing EA due to past patterns of failure.

Yoga in particular has been found to be an effective tool for youth to deal with stress and self-regulate emotions (for review, see Galantino, Galbavy, & Quinn, 2008; and Hagen & Nayar, 2014). Yoga involves focused attention on breath, a series of poses and postures, and meditation. Focused breath is thought to help focus the mind. Physical poses are thought to improve flexibility and strength. Meditation is thought to foster relaxation and help calm and focus the mind. Studies examining the effect of yoga in at-risk and traumatized youth suggest that yoga interventions have a positive impact on self-regulation and problematic responses to stress including rumination, intrusive thoughts, and emotional arousal (Mendelson et al. 2010; Spinazzola, Rhodes, Emerson, Earle, & Monroe, 2011). The practice of yoga, which integrates body movements with purposeful attention to breath, can help youth with their attention skills, which may improve school performance. Studies examining the impact of yoga interventions on youth with ADHD suggest yoga can improve attention and decrease other symptoms of ADHD (Haffner,

Roos, Goldsteiner, Parzer, & Resch, 2006; Jensen & Kenny, 2004; Peck, 2005). In school aged children with emotional and behavioural disorders, yoga produced improved attention and adaptive skills, and reduced depressive, behavioural, and internalizing symptoms (Steiner, Sidhu, Pop, Frenette, & Perrin, 2012).

Martial arts training includes both philosophical and meditation components. Martial arts differs from yoga in that the movements are faster and more dynamic (Milligan et al., 2015). MMA is the first known treatment to integrate mindfulness training into martial arts. However, yoga has been integrated with mindfulness in interventions for children with self-regulation disorders, such as ADHD (e.g., van der Oord et al. 2012). Vertonghen and Theebom (2010) reviewed the literature on martial arts in youth and found that while there is some controversy regarding the impact of martial arts training, the most recent research has pointed in the direction of the appearance of positive effects, including higher levels of self-regulation and psychological well-being and decreased aggression. Other research has suggested martial art has positive therapeutic effects such as improved body image and social relationships (Lakes & Hoyt, 2004; Zivin et. al., 2001). Martial arts training may enhance treatment by providing "active physical routes for the discovery and expression of emotion" (Weiser, Kutz, Kutz, & Weiser, 1995, p. 118). Persistence, flexibility, and trust in fellow group members are developed within the context of self-defense challenges. Nosanchuk (1981) suggests mechanisms of self-control, self-assertiveness, self-esteem, and self-confidence as instrumental in improving self-regulation in youth. Importantly with martial arts incorporated into MMA, the program provides a safe place for youth with LDs to be

involved in this socially valued recreational activity, which can be considered the 'hook' to engage youth who would not normally engage in treatment. Martial arts training is highly engaging and reduces the perceived stigma associated with receiving mental health care.

MMA: Previous research

Research on MMA has supported MMA as being a promising treatment option for youth with LD and co-occurring self-regulatory challenges. Milligan, Badali, and Phillips (2010) found that MMA had a positive impact on self-awareness and behavioural regulation. These results were supported by the findings of qualitative interviews, where parents and youth reported to be highly satisfied and felt the program was helpful. Parents specifically placed emphasis on the importance of milieu, where it appeared as though youth had a desire to better themselves and develop mastery in martial arts and be a part of a socially valued activity. Respondents also described the relationship with the MMA therapist, or sensei, as important.

Following this investigation, Haydicky et al. (2012) compared MMA participants with waitlist controls to better understand how MMA effects youth with LDs and co-occurring mental health challenges. Compared to the waitlist controls, MMA participants with co-occurring ADHD had decreased externalizing behaviour and oppositional defiant and conduct problems. Specifically, boys with elevated hyperactive/impulsive symptoms showed improvements on parent-rated social problems and monitoring skills. Boys with elevated inattentive symptoms improved on parent-rated social problems. Additionally, boys with elevated anxiety reported decreased anxiety at the end of treatment. In addition

to statistical significance, these results were also clinically significant with large effect sizes reported. Specifically, measures of partial eta-squared were reported ranging from 0.18 to 0.39 for the improvements in social problems, monitoring skills, and anxiety. These results suggest that the MMA intervention improved problematic psychosocial behaviours associated with LD in MMA participants, as compared to waitlist controls.

In a qualitative exploration, Milligan, Badali, and Spiroiu (2015) found that with MMA, youth had improved emotional well-being, self-understanding, communication, and peer relations. The practice of mindfulness may have decreased patterns of EA in these youth, as well as promoted a sense of calm, tolerance, and acceptance, which is especially important for these youth.

Psychophysiological Correlates

This previous preliminary research on MMA has suggested that the intervention may be effective in reducing the problem behaviours that often present in youth with LDs and self-regulation challenges. Specifically the evidence thus far suggests better self-regulation after intervention. However, we know little about how MMA may alter psychophysiological correlates of self-regulation. These psychophysiological correlates are important for indexing individual differences in the regulation of emotions and behaviours. If physiology underlies phenotypic expression, it is important to explore the physiological underpinnings that may underlie the phenomenon that the literature on MMA explores. Specifically, exploring psychophysiology in response to intervention is important for research as it can further establish the sensitivity of such correlates and add to the literature on the effectiveness of MMA as an intervention targeting self-regulation.

If psychophysiological correlates that are suggested to underlie and index the regulation of emotions and behaviours are found to be malleable and sensitive with intervention, this would suggest the intervention is altering how individuals regulate emotions and behaviours. This would ultimately provide evidence supporting the intervention as one that is effective in targeting and improving self-regulation.

Self-regulation. Self-regulation of behaviour is largely impacted by emotional arousal. Thayer and Lane (2000) propose emotions to be self-regulatory responses that allow for efficient coordination of the organism for goal-directed behaviour. Ideally, emotions should allow for flexible adaptation to changing environmental demands. Accordingly, disorders of affect, such as depression or anxiety disorders, can be characterized as an inability to shift into an emotion that is appropriate for a given set of environmental demands (Friedman & Thayer, 1998). This inability to shift is also manifested as inflexibility at other levels, such as the inability to shift into a behavioural pattern that is conducive to the varying demands of the environment. Similar to regulating affect, i.e., selecting an appropriate affective response, is selective attention which involves selecting meaningful information and disregarding irrelevant information. Thayer and Lane (2000) describe affective and attentional regulation as an integrated system that is responsible for self-regulation and adaptability, and can be indexed biologically.

Youth with LDs and co-occurring mental health issues struggle with regulating emotions and thus, have difficulty regulating behaviour. Additionally, deficits in executive functions negatively impact their ability to problem solve effectively. Emotion

and behaviour regulation, as well as executive functioning, can be index biologically with use of cardiac variability and specifically, respiratory sinus arrhythmia.

Respiratory sinus arrhythmia (RSA). Autonomic nervous system regulation, as manifested in cardiac variability, has been suggested to be related to both affect and attentional regulation (Porges, 1991, 1992; Richards & Casey, 1992; Thayer, Friedman, Borkovec, Johnsen, & Molina, 2000). The intensity of emotional responding while interacting with the environment is associated with varying degrees of cardiac variability. With environmental demands, the heart beats either faster or slower, at either a regular or irregular rate. Heart rate variability (HRV) indexes this physiological concept where the time interval between heart beats varies. Indices of HRV, such as respiratory sinus arrhythmia (RSA), have been shown to be related to self-regulation.

RSA represents a natural variation in heart rate that is associated with the respiratory cycle. Resting RSA is an index of cardiac vagal tone because its effects are largely due to the activity of the vagus nerve (Porges, 2007), the principal branch of the parasympathetic nervous system. Katona and Jih (1975) hypothesized that RSA is a non-invasive measure of parasympathetic cardiac control. The cardiovascular system is under inhibitory control via the vagus nerve, which is mediated by acetycholine. This natural variation in the cardiac signal, represented as RSA, results from increases in vagal activity on the heart during exhalation which decelerates heart rate, and decreases in vagal activity on the heart during inhalation which accelerates heart rate. Simply, the stimulation of parasympathetic fibres (vagus nerves) cause slowing of the heart and stimulation of sympathetic fibers (stellate ganglion) cause cardiac acceleration. RSA is

the natural log equivalent to high-frequency HRV, ranging from 0.12 to 0.4 Hz, and is commonly used to index phasic vagal cardiac control in humans (Berntson et al., 1997).

The way in which RSA, or cardiac vagal tone, can index attentional control and emotion regulation is through central-peripheral feedback mechanisms. Thayer and Lane (2000) describe this connection as a functional unit, named the central autonomic network (CAN; Benarroch, 1993), where the brain and heart communicate. This CAN is an integrative component of an internal regulation system, through which the brain controls both internal and external responses critical to goal-directed behaviour and overall adaptability to external surroundings. There are several structures involved in the CAN but specifically the prefrontal cortex (PFC) and its subcortical inhibitory circuits including the central nucleus of the amygdala play a critical role in self-regulation (Thayer & Lane, 2000). This circuit exhibits inhibitory control over sympathetic influences on subcortical circuits, making it possible to respond in a way that is optimal depending on the situational demand. Under normal circumstances, the PFC identifies safety cues from the environment and exerts this inhibitory control. In threatening and uncertain situations, this inhibitory regulation from the PFC diminishes in order to allow for default threat responses.

This network feeds neural information to the sinoatrial node of the heart via the vagus nerve and stellate ganglia. The interplay of these inputs causes this variability. The output of the CAN is directly linked to heart rate variability and higher resting HRV is associated with effective functioning of prefrontal-subcortical inhibitory circuits that support flexible and adaptive responses to environmental demands (Thayer & Lane,

2000). Thus, this variability provides a window into the bidirectional influences that link frontal lobes with modulation of cardiovascular function, referred to as "top-down" and "bottom-up" processes. Broadly, these ''top-down'' influences are brain pathways through which higher cortical structures influence autonomic function, interacting with ''bottom-up'' processes involving the transfer of information between the heart and lower cortical centers. Therefore, heart rate variability can be viewed as an index of integration between the central and nervous systems.

RSA and emotion regulation. In recent years, RSA has received increased attention as a psychophysiological index of emotion regulation, stress reactivity, and vulnerability in both clinical and nonclinical adult and pediatric populations (see Porges, 2007, for a review). Through the organization of physiological resources and appropriate response selection towards goal-directed behaviour, RSA may quantify the ability to self-regulate. Thus, the greater the amplitude of organized rhythmic physiologic variability, the greater the flexibility and possible range of behaviours, as this rhythm may index the status of the individual's nervous system and capacity to respond.

As a marker of physiological regulation, higher levels of resting RSA have been linked to greater emotional/behavioral flexibility (Porges, 1991, 1992) and healthy coping responses to stress (Gyurak & Ayduk, 2008). Conversely, lower levels of resting RSA have been associated with anxiety (Friedman, 2007; Friedman & Thayer, 1998; Lyonfields, Borkovec, & Thayer, 1995), worry (Brosschot, Gerin, & Thayer, 2006), negative emotional arousal and less effective coping in the presence of stress (Fabes & Eisenberg, 1997). Individual differences in resting RSA have been linked to stress

vulnerability (Porges, 1992; 1995) and emotion regulation (Brosschot, van Dijk, & Thayer, 2007) and emotional reactivity (Kettunen, Ravaja, Naatanen, & Keltikangas-Jarvinen, 2000) in typical populations, with higher levels being associated with more optimal self-regulatory behavior (Thayer & Lane, 2000). Taken together, the combined findings suggest that higher resting RSA may be a physiological manifestation of psychological flexibility (i.e., greater behavioral and/or emotional flexibility).

The way in which anxiety may be related to lower levels of RSA stems from anxiety's characteristic feature of increased sympathetic activation, or the "fight or flight" branch of the autonomic nervous system (Cannon, 1929). Since sympathetic influences on cardiac control are relatively slow compared to parasympathetic (vagal) influences, Thayer and Lane (2000) suggest that when fast vagal modulation of cardiac function is decreased, it is more difficult to track rapid changes in the environment and therefore more difficult to organize an appropriate response. Porges (2007) refers to this as the ability to engage and disengage the "vagal brake". Vagal withdrawal during stress may be an adaptive response that helps one's system to prepare for stress or challenging situation. Thus, a high degree of vagal control allows for enhanced and adaptive responsivity to changing environmental demands (Friedman & Thayer, 1998). A reduction in vagally mediated cardiovascular control at rest has been associated with a variety of pathological states and dispositions, such as mood and anxiety disorders.

RSA and executive function. The association between RSA and EF is related to the common neural basis for both functions. Activity in the PFC has been associated with cardiac control and RSA (Ahern et al., 2001), as well as tasks involving EFs such as

working memory, sustained attention, behavioural inhibition, and general mental flexibility (Arnsten & Goldman-Rakic, 1998). Ahern et al. (2001) found that inactivation of the PFC is associated with decreased RSA, while Fuster (2000) found that an intact PFC is necessary for efficient performance of many tasks that involve EF. Higher resting RSA has been linked with better EF (Thayer, Hansen, Saus-Rose &, Johnsen, 2009). Specifically, high resting RSA was found to be predictive of better sustained attention in 9-11 year olds (Seuss, Porges, & Plude, 1994).

While this pattern of high resting RSA related to better EF and attention seems to be consistent across studies, there is also a hypothesis suggesting changes in RSA during such tasks may index mental effort and attention (Seuss et al., 1994). This hypothesis is similar to Porges' (2007) adaptive ability to engage and disengage the "vagal brake" when preparing for challenging situation. Infant studies have supported this hypothesis, by showing that RSA is reduced during mental loading or sustained attention. A decrease in RSA has been observed during sustained attention of attention in 14-26 week old infants (Richards & Casey, 1991).

RSA in children and youth. Anxiety has also been reliably associated with lower levels of RSA in children and youth. Kagan et al. (1990) found that extremely shy children who may be at risk to develop adult anxiety disorders have diminished heart rate variability. Additionally, youth with anxiety disorders have lower resting RSA compared to their non-anxious peers (Blom, Olsson, Serlachius, Ericson, & Ingvar, 2010; Sharma, Balhara, Sagar, Deepak, & Mehta, 2011).

Research on adolescents with externalizing behaviours has revealed patterns of RSA that differ from adolescents without these behaviours. In adolescent males, antisocial and hostile behavior has been linked to lower levels of resting RSA in adolescent males (Mezzacappa et al., 1997; Sloan et al., 1994). Although there is contradicting literature regarding the relation between RSA and aggression, the recent evidence supports a negative association between RSA and aggressive behaviours in males aged 7 to 16. Mezzacappa et al. (1997) found that resting RSA was negatively associated with antisocial behaviour in adolescent males. Pine et al. (1998) reported that lower resting RSA was associated with externalizing problems in adolescent males at risk for later delinquency. Such trends seem to be exaggerated in males, as compared to females. Gordis, Feres, Olezeski, Rabkin, and Trickett (2010) found RSA was associated with aggressive behaviours in boys, but not girls, and Beauchaine, Hong, and Marsh (2008) reported that boys, but not girls, with conduct problems whose parents revealed them to have high aggression had lower resting RSA than boys who exhibited lower aggression. Additionally, Shibagaki and Furuya (1997) found that children with ADHD displayed lower RSA compared to control children.

With the research suggesting youth with LDs may have elevated levels of anxiety and problems with emotion and behaviour regulation, it may be the case that these youth have elevated sympathetic nervous system activity and thus have lower resting RSA. With their elevated avoidance patterns, these youth may be in a heightened state of hypervigilance even during baseline conditions. Sympathetic nervous system activity is triggered in response to a physical or psychological stressor, leading to a cascade of

behavioural, psychological and physiological effects such as the release of catecholamines (epinephrine and norepinephrine). This response leads to the mobilization of energy needed to combat the stressor through the classic ‘‘fight or flight’’ syndrome. Over time, the constant state of hyper vigilance resulting from repeated firing of the sympathetic nervous system can lead to dysregulation of the system. With this hyper vigilance, the PFC does not work to inhibit sympathetic influences on the amygdala and limbic regions. Additionally, research has shown activity in the amygdala is inversely associated with activity in the PFC (Davidson, 2000), suggesting executive functions are not readily available for these youth when they are hyper vigilant.

Malleability of RSA with intervention. If measures of heart rate variability are reflective of individual differences in emotion regulation and self-regulation, interventions that target these regulatory capacities may serve to increase these measures. Research in this area has suggested that these autonomic measures are malleable. However, here is mixed literature on the impact of mindfulness-based treatments on heart rate variability indices. For example, Tang et al. (2009) found that after a five day “integrative body-mind training” course incorporating meditation and mindfulness training, participants had significantly higher RSA compared to participants assigned to a control group involving relaxation training. However, other studies have failed to find significant increases in HRV indices including RSA after mindfulness-based treatments that ranged from 10 days (Krygier, Heathers, Shahrestani, Abbott, Gross, & Kemp, 2013) to 8 weeks in length (Bhatnager et al., 2013; Wheeler et al., 2014). These investigations all found significant improvements in the phenotype of interest (such as depression,

wellbeing, etc.), however there was no significant change in the physiological index that was hypothesized to correlate with the phenotype (such as HRV indices). This literature suggests mindfulness-based treatment may improve HRV indices, including RSA, but this improvement is not consistently found throughout studies.

Other components of MMA have been previously found to improve HRV indices, such as CBT and yoga. Following CBT interventions, increased vagal tone has been found in patients with anxiety (Friedman and Thayer, 1993) and depression (Carney et al., 2000). Studies investigating the effects of physical exercise have yielded significant increases in measures of heart rate variability, including RSA (see Routledge, Campbell, McFetridge-Durdle, & Bacon, 2008). Yoga interventions specifically have also been associated with changes in heart rate variability. A review by Ross and Thomas (2010) has suggested yoga is as effective as, or better than, other forms of exercise in improving heart rate variability. Specifically, increased cardiac variability has been linked to the practice of yoga in various studies of this relationship (Friis & Sollers, 2012; Khattab, Khattab, Ortak, Richardt, & Bonnemeier, 2007).

This literature suggests that interventions consisting of CBT and/or yoga might improve RSA. However, improvements in RSA with mindfulness have not been well established and thus, it is important to further investigate this relation. If RSA is an index of emotion regulation, these interventions may have the potential to improve emotion regulatory capacities. Specifically it is not currently known how HRV indices may improve with mindfulness in youth with LDs and comorbid self-regulation challenges.

Heart period. Another cardiovascular psychophysiological measure that has been linked to psychological stress, emotion regulatory processes, and individual differences in these processes is heart period (HP; the interbeat interval and inverse of heart rate). HP (or its inverse, heart rate) is the result of the competitive innervation of the heart by the sympathetic and parasympathetic nervous systems (Cacioppo, Uchino, & Bernston, 1994). Low HP is an index of greater sympathetic activity (Kagan, Reznick, & Snidman, 1988). Individuals with this resting pattern of low HP can be viewed as in a constant state of hypervigilance or entrenched in the classic "fight or flight" syndrome. Low HP has been linked to shyness, behavioral inhibition, anxiety, negative affect, emotion dysregulation, and related constructs in clinical and nonclinical samples in adults and children (Kagan, Reznick, & Snidman, 1988; Schmidt & Fox, 1994). Additionally, high heart has been the best-replicated biological correlate to date of antisocial behavior in children and adolescents (see Ortiz & Raine, 2004). Heart rate has been found to be decrease following a CBT intervention in adults with depression (Carney et al., 2000), suggesting it may also be malleable with intervention.

The Present Study

While a large body of research on youth with LDs has suggested extensive deficits in areas such as social interactions, emotion and behaviour regulation, and executive functions, this group has been noted as one of the most ignored in terms of mental health services and psychological research into therapeutic techniques (Reed, 1997). Few mental health treatments have been modified for youth with LDs or other information processing difficulties (Moree & Davis 2010).

Previous research on the effectiveness of mindfulness interventions for youth with LDs and associated mental health challenges, and MMA specifically, have yielded promising results on a behavioural, emotional, and cognitive level (Beauchemin et al., 2008; Haydicky et al., 2012; Milligan et al., 2010; Milligan et al., 2015). Beauchemin et al. (2008) assessed the feasibility of a mindfulness-based intervention for adolescents with LDs, which is important for the investigation of MMA as it suggests this population have the potential to benefit from such an intervention. However, MMA differs from the mindfulness meditation the Beauchemin et al. (2008) study, as MMA additionally provides a socially accepted recreational activity for these youth to participate in which takes place outside of the classroom. Additionally, Beauchemin et al. (2008) could not examine how the effects of mindfulness over a 5 week period may compare to 'treatment as usual' for these youth, as there was no control group to compare results to. Similarly, while investigations of MMA are promising (Milligan et al., 2010; Milligan et al., 2015), these explorations were conducted in the absence of a control group. Without a control group, there is the possibility that improvements in these youth are due to confounding factors and not only the MMA intervention. With use of a control group that does not participate in MMA, improvements in the treatment group may be more confidently attributed to the intervention alone, if no improvements in the control group are found. Importantly, it is still unknown how self-regulation may be targeted with MMA on a physiological level, as well as how mindfulness-based treatment programs may improve executive functioning or target avoidance behaviours in youth with LDs and mental health challenges.

The present study investigated how measures of autonomic activity were altered over the course of an MMA intervention in adolescent males with LDs and co-occurring self-regulatory challenges. With MMA targeting self-regulation, it is important to investigate how psychophysiological correlates of self-regulation may change in response to the intervention. If psychophysiological correlates of self-regulation are altered in response to MMA, this would further establish both the effectiveness of the intervention, suggesting the intervention is targeting self-regulation, and the sensitivity of the measure, suggesting the measure is malleable with intervention. With the connection between physiology and the regulation of behaviour and emotions that has been well established in the literature, improving physiological correlates of self-regulation with MMA provides convergent evidence for the intervention that parallels the previous behavioural findings (Haydicky et al., 2012; Milligan et al., 2010; Milligan et al., 2015).

The primary hypotheses investigated how heart period (HP) and respiratory sinus arrhythmia (RSA) may be altered with MMA. If MMA improves self-regulation capacities, this intervention may serve to increase physiological indexes of self-regulation. Compared to wait-list controls, I predicted HP would increase after MMA, as low HP is characterized in the literature as associated with behavioural inhibition, anxiety, and emotion dysregulation. However, the literature also suggests an association between low HP and antisocial behaviour. Given this association and the behavioural challenges that present in youth with LD, HP may increase after intervention in the youth with these specific challenges. With RSA as a psychophysiological index of self-regulation and emotion regulation, I hypothesized that RSA would increase after the

MMA intervention. I also explored how measures of EF may improve with MMA. Previous research has suggested EF may be improved with exercise (Best, 2010) and mindfulness practices (Flook et al., 2010). Thus, I predicted these components of MMA would contribute to better cognitive control and hypothesized that problem scores of EF would decrease after MMA.

The present study was completed as part of a larger evaluation of MMA carried out at Ryerson University in Toronto, Ontario, Canada and represents an analysis of early pilot data collected for the evaluation of youth enrolled in beginner MMA.

Method

Eligible Participants

Adolescent males who participated in the present study were clients of the Integra Foundation, now known as the Integra program at the Child Development Institute, an agency serving youth and their families dealing with mental health issues complicated by LDs in Toronto, Ontario. Eligible participants were males between the ages of 12-18 years old, had previously been diagnosed with an LD by a registered psychologist or psychological associate, and were either currently enrolled in (MMA) or on the waitlist (WL) for Integra services.

All participants had undergone cognitive and academic testing outside of the study. The psychoeducational assessment report for each child was reviewed to confirm a diagnosis of LD and more specifically that they met the following three criteria. Firstly, they had average to above-average level of intellectual functioning, as assessed by the Wechsler Intelligence Scale for Children (WISC-IV). Specifically, participants had to

obtain a score between 90 to 109, which is within the 25th and 75th percentile, for either the full scale IQ or in at least one area (verbal comprehension and perceptual reasoning). Secondly, participants had to have significantly lower academic ability in at least one area compared to their level of cognitive ability, using a standardized test of academic ability such as the Wechsler Individual Achievement Test, which examines deficits in areas such as oral language, reading, written language, and/or mathematics. Lastly, participants had to present with challenges in at least one area of information processing, such as language processing, phonological processing, visual spatial processing, processing speed, memory and attention, and executive functioning.

MMA Program Description

MMA is an evidence-informed manualized group treatment program developed at Integra in 2002. MMA is specifically designed for youth ages 12-18 years old with LDs and co-occurring self-regulation challenges. The beginner program consists of 20 weekly sessions (1.5 hours in length) followed by brief meetings with youth and parents. Each session is comprised of 8-10 youth and take place in a dojo, which is a Japanese term referring to a formal training place for students of martial arts. The sessions are led by Child and Family Therapists with Master's degrees in Social Work or Drama Therapy. These MMA instructors hold advanced belts in martial arts and are experienced practitioners of yoga, mindfulness meditation, and cognitive behaviour therapy.

MMA integrates mindfulness, cognitive therapy, and behaviour modification and activation into the practice of yoga and mixed martial arts. The core components of the program are conceptually linked by the overarching theme of Bushido, or Way of the

Warrior. Bushido, a Japanese tradition of meditation and combat arts, is based on the philosophy that fear is conquered through self-examination and self-knowledge (Cleary, 2005). MMA participants are challenged to explore their inner world and accept their thoughts and feelings without judgment.

The specific mindfulness concepts emphasized in the MMA program are impermanence, awareness and acceptance of the present moment, non-judgmental observation, and letting go. From this focus on the present moment, youth learn that they can choose how they react to challenges rather than reacting in an automatic or reflexive manner. MMA uses two formal mindfulness approaches: mindfulness meditation and the mindful moment. The practice of mindfulness meditation includes sitting meditations (e.g., loving kindness meditation, which is designed to develop a loving acceptance of oneself and overcome feelings of self-doubt), body scans, which focuses on an awareness of the different regions of your body, and the experience of how each part feels without trying to change anything, and Kinhin/walking meditation, which includes breath and body sensation awareness. The length of formal meditation is gradually increased each week. In early sessions, students use concentrative meditations to improve self-regulation of attention. During these meditations, students may use a mantra, which are often word(s) or sound(s) repeated to aid concentration or act as a focal point to help focus their mind. Once they have mastered concentrative meditation, students are introduced to receptive meditation, where there is no specific object of attention. During receptive meditations, the individual is open to all experiences that may arise during the meditation. This practice of mindfulness meditation provides an

opportunity for youth to increase awareness of thoughts and feelings, and to practice non-judgmental observation, acceptance, and letting go. The mindful moment is an adaptation of the 3-minute breathing space developed by Segal et al. (2002) for an adult population. Breathing spaces are ‘‘mini meditations’’ were a person reflects on what is happening in the present moment. These mini meditations involve acceptance and it is this acceptance that creates space for both positive and negative thoughts and feelings. During the mindful moment, youth are asked to (1) focus on their breath (saying the word ‘‘BE’’), (2) open and soften, and (3) note their experience. The mindful moment is a non- striving action, which involves actively being present with one's experience without having to work towards anything (Milligan et al., 2015). The self-awareness and present-focus mindset associated with mindfulness practice sets the stage for integration of cognitive strategies, such as mindful self-talk.

During MMA sessions, youth are presented with statements or mantras such as "it will change," "Be," etc. Therefore, youth can learn that they can say these positive statements to themselves in times of discomfort or challenge. Such mindful self-talk mantras are posted on the wall of the dojo to accommodate for memory weakness. Students are cued to use these self-talk mantras in the context of their meditation, yoga, and martial arts practice.

Each of these therapeutic components is embedded into the practice of yoga and martial arts, which are viewed as complementary activities (Milligan et al., 2015). For these youth, yoga provides an opportunity during posture performance (e.g., chair pose) to practice staying present, accepting challenges, and using self-talk. Similar to yoga and

the presentation of a challenge that must be observed and accepted is the practice of martial arts, where youth have an opportunity to practice skills in the context of interaction with another (i.e., an opponent).

With the high occurrence of experiential avoidance within this population, behaviour activation and modification strategies are often utilized to motivate youth to fully participate in MMA. These strategies also serve to structure and encourage the use of newly learned skills outside of sessions. Specifically, Barkley's (1997) response-cost point system keeps youth accountable for their actions both in and out of the MMA treatment session. This response-cost system promotes adaptive behaviours such as attendance, participation, compliance, pro-social behaviour, home practice, progress towards personal goals, and indications of improvement in any of the core components of the program. Points are earned from these behaviours. Alternatively, if youth do not participate in enough home practice or are not compliant during the treatment session, points would not be given to these youth. Additionally, push-ups may be assigned if the youth are late or are having trouble staying on task and need help focusing. When students reach predetermined point levels, they are promoted to the next belt level (white stripes or yellow belt). Student achievements are recognized in Weeks 5, 10, and 15 of the program, which are known as "stripe weeks". Stripes, which indicate progress towards the next belt, are awarded to youth with enough points. Alternatively, recognizing achievements can also be accomplished through phone calls to their parent/guardian.

After each MMA session, brief individual meetings (8 minutes long) are held with the sensei, parent, and youth. These meetings serve to promote generalization of

strategies and concepts outside of the treatment setting, as well as update the sensei on any progress with personal goals outside of the treatment setting. Youth are provided with a CD that guides and supports them in practicing meditation at home (e.g., loving kindness meditation, body scan). Points are earned for home practice completion.

Each MMA session includes five phases. Sessions start with a brief sitting meditation. Then, students learn the skill of that week. The skill is a therapeutic lesson such as creating space for challenging situations, thoughts, and emotions. The sensei will then present the case, which is a story presentation of the skill and the application, which is applying the skill in meditation. The last two phases of the MMA session consist of a yoga warm-up and martial arts training. During these last two phases, the skill is embedded into the meditation, yoga, and martial arts elements of the session. Table 1 provides an example of a typical MMA session and highlights the integration of therapy and physical exercise (adapted from Milligan et al., 2015, Integra & Badali, 2002). This sample session is built around the skill of "it will change", and teaches students that everything changes and nothing stays the same. Youth with LDs and self-regulatory challenges often see negative life events to be stable and unchanging. In this session, students learn to tolerate discomfort, which sets the stage for later lessons of accepting discomfort. The introduction of ''it will change'' is liberating for youth and allows them to experiment with tolerating discomfort even for a short moment. The skill ''it will change'' is then practiced within the practice of a yoga warm-up and mixed martial arts. These two activities provide the opportunity to participate in activities that require a

present-focus. Additionally, these physical challenges push youth to the edge of their comfort level, while keeping in mind that the discomfort is temporary and is tolerable.

The core mindfulness, cognitive therapy, and martial arts components are integrated into each session and connected by a unifying concept. For example, the concept of "no lingering" introduced in Week 13 is related to mindfulness (observing thoughts as only passing events), cognitive therapy (reducing rumination), and martial arts (responding quickly when sparring). Concepts and skills are introduced gradually through didactic teaching, modeling, role-playing, and scaffolding by the sensei. Sessions are tailored in depth and style of instruction depending on the physical fitness, memory, and coordination of the individuals in the treatment group.

Experimental Design

A waitlist control design was used, rather than random assignment, due to ethical considerations. Most families are placed on a waitlist to receive services at Integra for at least a year and therefore, it would be unethical to further delay entry. Data were collected at three time points; Pre-intervention took place during Week 1 of MMA; Post-intervention took place after 20 weeks of MMA; Follow-up took place 3 months after completion of MMA.

Data collection took place in two cohorts whose data were combined to increase sample size and statistical power. Data from the first cohort were collected from February to September 2013 and those from the second cohort were collected from February to September 2014. To examine similarities and differences between the two cohorts on any demographic variables or study measures, two-way contingency tables and independent

samples *t*-tests were conducted (See Table 2). The two cohorts did not significantly differ on these variables and this allowed us to combine them to increase sample size.

Procedure

Prior to beginning the MMA program, youth and their parents attended an information session led by the lead instructor where the goals, expectations, and potential risks of participation in MMA were outlined. The research program was also explained including the purpose, time commitment, reimbursement, procedure, and potential risks. Participants and their families were told participation in the research program was not mandatory for participation in the MMA program, and that electing not to participate would not impact any relations with Integra. Parents who elected to participate in the research were given a package containing an information package and consent form, and a visit to the lab was scheduled to begin data collection.

Control participants were recruited from the waitlist for the MMA program. Parents were contacted by email by the Integra intake coordinator. This email explained the research study including the purpose, time commitment, reimbursement, procedure, and potential risks. Once parents gave verbal assent to be contacted regarding the study, a research assistant from Ryerson University (where the testing took place) contacted the family. The family then received an email with the information package and consent form, and a visit to the lab was scheduled to begin data collection. These waitlist controls were offered early admission to Integra and the MMA program after completing all visits required for the research program.

Each testing session was approximately 2.5 to 3 hours in length. Upon arrival at the laboratory, the study was described to youth and verbal assent was obtained. Participants and their parents were familiarized with the testing environment followed by a briefing on the procedures. As part of a larger study, at each visit, participant's heart rate was recorded with use of electrocardiogram (ECG) and participants and their parents completed outcome measure questionnaires. Youth were told they could skip any items or withdraw from the study at any point, without penalty. All participants were compensated $25 for each testing session attended. Laboratory procedures were conducted by trained research assistants and approved by Ryerson University Research Ethics Board.

Measures

Demographics. A demographics questionnaire was completed by parents at the pre-intervention visit only. This questionnaire consisted of questions pertaining to the child's health history, ethnicity, and household income. From this questionnaire, BMI was calculated with use of height and weight. Additionally, parents revealed current medications and any other therapy or fitness activities the adolescents were currently involved in.

Mini International Neuropsychiatric Interview for Children and Adolescents (MINI-KID). The MINI-KID (Sheehan et al., 1998) is a structured diagnostic interview for children and adolescents (ages 6 to 18 years old), as well as their parents. The interview was administered by graduate students, under the supervision of a child clinical psychologist, to youth and their parents at the pre-intervention visit only. The interview assesses the presence of 24 DSM-IV child and adolescent psychiatric disorders as well as

the risk of suicide. Inter-rater and test-retest reliability correlations range from .64 to 1.00 for all individual MINI-KID disorders except dysthymia. Additionally, high concordance between the parent version (MINI-KID-P) and the standard MINI-KID has been found.

Conners 3rd Edition. The Conners 3 (Conners, 2008) is used to screen for ADHD in youth. The Conners 3 assesses inattentive, hyperactive and impulsive symptomology and comorbid problem areas such as executive function, defiance and aggression, and peer and family relations. *T*-scores, linear transformations of the raw scale scores, provide information about the individual's scores relative to the scores of respondents in the standardization sample. *T*-scores greater than 70 suggest ADHD symptoms within that specific problem area, such as inattentive and/or peer relations, fall within the clinical range. Thus, this tool is able to identify clinical subtypes of ADHD. The parent-report form can be used for children ages 6 to 18, while the self-report form can be used with children ages 8 to 18 years old. Internal consistency reliability coefficients range from .77 to .97, while test-retest reliability coefficients range from .71 to .98, and inter-rater reliability coefficients range from .52 to .94.

Behavior Rating Inventory of Executive Function (BRIEF). The BRIEF (Gioia, Isquith, Guy, & Kenworthy, 2000) questionnaire assesses everyday behaviours within the school and home environments associated with specific domains of executive function in youth aged 5 to 18 years old. The BRIEF can be completed by both parent and youth. There are two broad index scales, behavioural regulation and metacognition, as well as a global executive composite. The behavioural regulation index consists of three subscales: the inhibit subscale measuring inhibitory control and impulsivity, the shift

subscale assessing the ability to move freely from one situation or activity to another as circumstances demand, and the emotional control subscale which examines the ability to modulate or control emotional responses. The metacognition index consists of five subscales: the initiate subscale reflecting the ability to begin a task or activity and to independently generate appropriate ideas, responses, or problem-solving strategies, the working memory subscale which measures the capacity to hold information in mind for the purpose of completing a task or generating goals, plans, and sequential steps to achieve goals, the plan and organize subscale assessing the ability to manage current and future-oriented task demands, the organization of materials subscale measuring orderliness of work, play, and storage spaces, and the monitor subscale which assesses task-oriented monitoring such as work-checking habits, and self-monitoring such as interpersonal awareness. The global executive composite is an overarching summary score that incorporates all of the BRIEF subscales. *T*-scores, linear transformations of the raw scale scores, provide information about the individual's scores relative to the scores of respondents in the standardization sample. Elevated *T*-scores on these subscales and index scales suggest difficulty with that aspect of executive function. Test-retest reliability coefficients are around .82, while internal consistency reliability coefficients range from .8 to .98.

Defining the sample

The total sample consisted of 24 participants (19 MMA, 5 WL). Participants in the sample ranged from 12 to 16 years of age (total sample M=13.9, SD=1.3; MMA M=14.05, SD=1.31; WL M=13.2, SD=0.84). Body Mass Index ranged from 14.2 to 23.1

(total sample *M*=18.3, *SD*=2.4; MMA *M*=18.9, *SD*=2.16; WL *M*=16.4, *SD*=2.25). 82.6% of the sample were Caucasian (*n*=19; 16 MMA, 3 WL), while 8.7% were of Afro-Canadian descent (*n*=2; 1 MMA, 1 WL), and 8.7% classified themselves as other when asked about their ethnicity (*n*=2; 1 MMA, 1 WL). For household income, 29.2% reported less than $50,000 (*n*=7; 5 MMA, 2 WL), 25% reported between $50,000 and $100,000 (*n*=6; 3 MMA, 3 WL), 20.8% reported between $100,000 and $150,000 (*n*=5; 5 MMA), 8.3% reported between $150,000 and $200,000 (*n*=2; 2 MMA), and 16.7% reported more than $200,000 (*n*=4; 4 MMA). Approximately 25% of participants (*n*=6; 5 MMA, 1 WL) reported taking medication such as antidepressants (specifically, selective serotonin reuptake inhibitors or SSRIs), stimulants, and anti-psychotics while enrolled in the study. 87.5% of participants (*n*=21; 17 MMA, 4 WL) reported participation in other sports and physical fitness activities. Of the WL participants revealing such participation, the fitness activities reported included baseball, hockey, karate, swimming, etc.

To further define the sample, the MINI-KID-P was used to describe the presenting problems in these youth. Based on this parent report, youth met criteria for the following diagnoses: ADHD- Inattentive subtype (81.8%, *n*=18; 14 MMA, 4 WL), ADHD-Hyperactive/Impulsive subtype (22.7%, *n*=5; 4 MMA, 1 WL), social phobia (31.8%, *n*=7; 6 MMA, 1 WL), major depressive disorder (13.6%, *n*=3; 3 MMA), pervasive developmental disorder (13.6%, *n*=2; 1 MMA, 1 WL), specific phobia (9.1%, *n*=2; 1 MMA, 1 WL), generalized anxiety disorder (9.1%, *n*=2; 2 MMA), suicidality (4.5%, *n*=1; 1 MMA), current hypo-manic or manic episode (4.5%, *n*=1; 1 MMA), panic disorder (4.5%, *n*=1; 1 MMA), agoraphobia (4.5%, *n*=1; 1 MMA), obsessive compulsive disorder

(4.5%, *n*=1; 1 MMA), tic disorders (4.5%, *n*=1; 1 MMA), and anorexia nervosa (4.5%, *n*=1; 1 MMA).

Consistent with literature that suggests youth with LDs often struggle with comorbid mental health challenges (Mayes & Calhoun, 2006), I investigated how many comorbid disorders the participants presented with, according to the MINI-KID-P, to better understand the complex comorbidity of the sample. Based on this parent report, youth met the criteria for either no comorbid disorders (12.5%, *n*=3; 3 MMA), one comorbid disorder (33.3%, *n*=8; 5 MMA, 3 WL), two comorbid disorders (16.6%, *n*=4; 4 MMA), three comorbid disorders (12.5%, *n*=3; 2 MMA, 1 WL), four comorbid disorders (12.5%, *n*=3; 3 MMA), or five comorbid disorders (4%, *n*=1; 1 MMA). Data for the MINI-KID-P was not collected for two participants (1 MMA, 1 WL).

To ensure waitlist controls and MMA participants did not differ on any demographic variables or study measures at the pre-intervention visit, two-way contingency tables and independent samples *t*-tests were conducted (See Table 3). Waitlist controls and MMA participants were not significantly different on these variables at the pre-intervention visit and this allowed us to conclude the two groups were sufficiently similar at the start of the study.

ECG recording

Participants' ECG was recorded using two electrodes, as part of a larger electroencephalogram (EEG) study. One electrode was placed below the participant's right clavicle, and one was placed on the left side of the ribcage close to the heart. Although a recording of 1 minute is sufficient to assess RSA, recordings of 5 minute are

recommended for comparison of short recordings across studies (Task Force, 1996). Respiration rate was not monitored in this study. While statistical control of respiration may be implemented to ensure that respiration rate does not influence RSA, spontaneous respiration rates during seated rest are generally slow enough to avoid any undue influence of respiration on RSA (Berntson et al., 1997; Denver, Reed, & Porges 2007). Research on the effect of respiration on ECG recordings demonstrates that the amplitude of RSA is not affected by respiration frequency under baseline conditions (Denver et al., 2007), and therefore respiration frequency is unlikely to be a concern for the present study, where resting state was of primary interest.

Rest task. During a 5 minute resting task, participants listened to instructions from a pre-recorded female voice in a sound proof and electrically shielded room. Participants were instructed to open and close their eyes. When their eyes were closed, a black screen was displayed in front of them. When their eyes were open, a screen with stars was displayed in front of them.

Selective auditory attention task. Participants were seated in a sound proof and electrically shielded room. Two digitized sounds were presented using two speakers, one to the left of the participant and one to the right of the participant. Participants were instructed to attend to one ear only and to ignore all sounds presented to the other ear. While remaining visually fixated on a cross at the center of the computer screen, they were asked to respond by pressing a number on a key pad when they heard the target tone in the attended ear, and not to respond otherwise. Task instructions were presented in written form on the computer monitor while concurrently read aloud by a research

assistant. Stimuli consisted of a 1000 Hz (88% probability, nontarget) and a 2000 Hz (12% probability, target) 200 ms tones. During an initial practice block, participants were presented with an example of each type of stimulus and asked to perform 10 practice trials whereby sounds were presented with a variable inter-stimulus interval of 600 - 800 ms randomized across ears. The test trials included four blocks of 200 trials each. Trial breakdown across the entire task was as follows: forty-eight 2000 Hz tones presented to the attended ear (attended targets), forty-eight 2000 Hz tones presented to the unattended ear (unattended targets), three-hundred and fifty-two 1000 Hz tones presented to the attended ear (attended non-targets), and three-hundred and fifty-two 1000 Hz tones presented to the unattended ear (unattended non-targets). All participants began the task attending to their left ear. After the completion of each 200-trial block, there was a 20-s break where participants were instructed to press the space bar when they were ready. Participants were then asked to switch their ear of attention and to respond to target tones in that ear only. The task took approximately 15 minutes to complete.

ECG quantification

A file of interbeat intervals (IBIs) was created for each participant for the 5-minute ECG recording, using ActiView and BioSemi software in BDF file format. The IBI data were visually edited for artifact (missing or spurious R-waves) using MindWare Heart Rate Variability (HRV) Analysis Software. This program calculated the mean resting HP (ms) and RSA (ln ms^2) for each participant.

With use of MindWare Heart Rate Variability (HRV) Analysis Software (Version 3.0.22), HP and RSA were calculated. As heart rate is a non-linear transform of HP,

indices of HP are preferred over heart rate in autonomic research. Changes in HP are constant across the possible range of HP values, whereas changes in heart rate are not (Berntson, Quigley, & Lozano, 2007). RSA was calculated by extracting the amount of variability (ms^2) within the 0.12 to 0.40 Hz range (Berntson et al., 1997) from the cardiac signal. This range reflects both peripheral vagal efferent activity and central respiratory control mechanisms (Berntson, Cacioppo, & Quigley, 1993; Berntson et al., 1997) and is commonly used to assess high-frequency heart rate variability in clinical and non-clinical samples. These high-frequency power values were transformed using a natural log (ln) transform to normalize the distribution, yielding estimates of RSA.

Attrition and Data Loss

Attrition in the present study does not reflect retention within the MMA program at Integra. One participant (1 MMA) did not attend the post-intervention visit, but returned for the follow-up visit. Three participants (2 MMA, 1 WL) withdrew from research prior to the follow-up visit, for an attrition rate of 12.5%. These rates do not reflect all missing data within the dataset, as there are other sources of missing data such as technological issues with the ECG recording or incomplete questionnaires.

Data Analyses

Covariates. In the sample, psychotropic medications are used for reducing depression, anxiety, and ADHD symptoms, however some psychotropic medications are also known to affect autonomic functioning (e.g., heart rate and blood pressure; O'Brien & Oyebode, 2003), with unfavourable effects on parasympathetic activity (Licht, de Geus, van Dyck, & Penninx, 2009, 2010; Roelofse & van der Bijl, 1994). Thus,

medication use was entered as a covariate to the analyses with use of a dichotomized variable (yes vs. no medication use). RSA is said to increase during childhood, reaching a peak in the late teen years (Korkushko, Shatilo, Plachinda, & Shatilo, 1991). As RSA would be on its way to its peak with the age of the participants in this study, age was added into the analyses as a covariate. Additionally, greater body mass (BMI) has been associated with lower RSA in some studies (Molfino et al., 2009), and therefore was entered into analyses as a covariate.

Primary analysis: Change across time. To assess change across visits in autonomic measures and executive function and to attribute results to the MMA intervention itself, the analyses only consisted of data from the pre-intervention and post-intervention visits.

Group differences, changes across visits, and group by visit interactions were assessed in separate Group (WL/MMA) by Visit (pre/post) ANOVAs for resting HP and RSA, respectively. Additionally, paired *t*-tests were conducted to evaluate change in resting HP or RSA over time by group. To examine whether the HP or RSA groups differed between groups at both visits, independent *t*-tests were conducted. The stability of individual differences in resting HP and RSA between visits was assessed using Pearson correlational analyses. Group (WL/MMA) by Visit (pre/post) ANCOVAs for resting HP and RSA were also conducted with medication use, age, and BMI as covariates.

Group differences, changes across visits, and group by visit interactions were assessed in Group (WL/MMA) by Visit (pre/post) ANOVAs for executive function,

separately for parent- and adolescent self-reported BRIEF scores. Additionally, paired *t*-tests were conducted to evaluate change in executive function over time by group.

Results

Effect of Medication, BMI, and Age on Resting HP and RSA in the Sample

Since the sample included 6 participants on medication, I was interested in determining whether medication status affected resting HP and RSA. Using an independent *t*-test, I investigated whether HP and RSA were different among those on medication versus those not on medication. HP was not different between those on medication and those not on medication ($p > 0.10$). However, the independent *t*-test was significant for RSA ($t(22)=2.95$, $p < 0.007$). Specifically, resting RSA was lower in those on medication ($n=6$, $M=5.43$, $SD=1.53$) versus those not on medication ($n=18$, $M=6.89$, $SD=0.87$). BMI was not significantly correlated with resting RSA or HP in this sample ($ps > 0.37$). Age was also not significantly correlated with resting RSA or HP ($ps > 0.30$).

Primary Analysis: Change Across Time

Change across time: autonomic measures. Mean autonomic values by Visit and Group are presented in Figure 1 and Table 4. Data from the follow-up visit were eliminated from the analyses and only Visits 1 (pre) and 2 (post) are outlined in order to attribute the findings to the MMA intervention. A Group (WL/MMA) by Visit (pre/post) ANOVA with resting HP revealed no effects of Group or Visit ($ps > 0.58$) and a marginal interaction ($F(1, 18)=3.93$, $p < 0.06$). A similar Group (WL/MMA) by Visit (pre/post) ANOVA with resting RSA revealed no effects of Group or Visit and no interaction ($ps > 0.33$). With paired *t*-tests, I found no significant change across visits for HP and RSA for

either Group (ps > 0.12; See Table 4). Additionally, independent t-tests revealed no significant Group differences for HP and RSA at either Visit (ps > 0.13).

A Group (WL/MMA) by Visit (pre/post) ANCOVA with medication status, age, and BMI as covariates with resting HP revealed no significant effects of Visit, Group, or BMI (ps > 0.61). A significant between group effect of medication status ($F(1,10)=5.91$, $p < 0.04$) was found. Those on medication had marginally lower HP at both visits. No interactions were found (ps > 0.33). The same ANCOVA was performed for RSA revealed no significant effects of Visit, Group, Age, or BMI (ps > 0.25). A marginal between group effect was found for medication status ($F(1,10)=3.87$, $p < 0.08$). Those on medication had significantly lower RSA at both visits. No interactions were found (ps > 0.35).

Change across visits: executive function. Group (WL/MMA) by Visit (pre/post) ANOVAs were conducted to investigate change over time in parent- and adolescent self-reported BRIEF scores. Data from the follow-up visit were eliminated from the analyses and only Visits 1 (pre) and 2 (post) are outlined in order to attribute the findings to the MMA intervention. A significant effect of Visit emerged for the parent-reported subscale of emotional control ($F(1,21)=4.14$, $p < 0.05$). Significant effects of Visit were also found for the self-reported subscale of emotional control ($F(1,14)=15.9$, $p < 0.001$) and the self-reported index of behaviour regulation ($F(1,14)=5.15$, $p < 0.04$). With all subscales that produced significant effects of Visit, graphs revealed the BRIEF problem scores decreased from Visit 1 to Visit 2 for both the WL and MMA Groups. No significant effects of Group were found (ps > 0.10).

A marginal Visit by Group interaction was found for the parent-reported subscale of monitor ($F(1,21)=3.12$, $p < 0.09$), with the MMA Groups' scores decreasing from Visit 1 to Visit 2 and the WL Groups' scores increasing from Visit 1 to Visit 2. A significant Visit by Group interaction was found for the self-reported subscale of plan/organize ($F(1,14)=5.29$, $p < 0.04$), with the MMA Groups' scores staying the same across time and the WL Groups' scores decreasing from Visit 1 to Visit 2.

I had *a priori* predictions of the direction of change for the BRIEF problem scores in the treatment Group. Specifically, I expected that the means would decrease from Visit 1 to Visit 2 in the Group receiving the MMA intervention. Due to the fact that I had this *a priori* prediction, I did not correct for multiple comparisons with subsequent paired *t*-tests with the MMA participants. I observed a significant mean decrease from Visit 1 (M=68.27, SD=11.32) to Visit 2 (M=64.39, SD=9.62) on the parent-reported subscale of initiate ($p < 0.04$; See Figure 2a), suggesting parents rated their children as better able to initiate and generate ideas and problem-solving strategies on their own at the post-intervention Visit. A significant mean decrease from Visit 1 (M=68.33, SD=7.55) to Visit 2 (M=64.61, SD=9.17) was found on the parent-reported subscale of plan/organize ($p < 0.02$; See Figure 2b), suggesting parents rated their children as better able to plan and organize at the post-intervention Visit. A significant mean decrease from Visit 1 (M=69.44, SD=8.65) to Visit 2 (M=66.22, SD=8.71) was revealed on the parent-reported index` of metacognition ($p < 0.01$; See Figure 2c). This trend suggests an increased ability to initiate, plan, organize, self-monitor and sustain working memory at the post-intervention Visit, as reported by parents. Lastly, a significant mean decrease was found

from Visit 1 (M=56.82, SD=7.11) to Visit 2 (M=49.27, SD=10.57) on the self-reported subscale of emotional control ($p < 0.002$), implying an improvement in this domain at the post-intervention Visit.

In the wait-list control group, I also computed paired t-tests with parent- and self-reported BRIEF scores. Since this Group was not receiving the MMA intervention, my *a priori* prediction was that there would not be any significant mean changes across time. However, I did observe a significant mean decrease from Visit 1 (M=59.6, SD=5.89) to Visit 2 (M=51.8, SD=6.42) on the self-reported subscale of plan/organize ($p < 0.04$), suggesting an improvement in the ability to plan/organize at the post-intervention Visit.

Exploratory Analysis

I took this opportunity to probe other relations within the dataset, which is important for both exploring relations that already exist in the literature but have not yet been studied in this population, as well as important for hypothesis generating for future studies.

Change in autonomic measures from resting to task. The first exploratory analysis examined how autonomic measures may change from resting baseline to a selective attention task. Changes in HP and RSA during attention-demanding tasks may index mental effort (Seuss et al., 1994). The ability to regulate the autonomic nervous system to support an appropriate behavioural state may develop with MMA and thus, I predicted that only after intervention, HP and RSA would decrease during the selective attention task. This investigation into whether HP or RSA changed from during the resting baseline condition to the selective attention task at either visit was assessed with

separate Visit (pre/post) by Condition (rest/task) by Group (WL/MMA) ANOVAs. Separate paired *t*-tests were then conducted with HP and RSA from rest to task at each visit, by group. For this research question, I included data from the follow-up visit.

For HP, there were no significant effects of Visit or Group (ps > 0.39). There was, however, a significant effect of Condition ($p < 0.002$), with higher levels of HP during the task. There were no interactions found between Visit, Condition, and/or Group (ps > 0.45). Subsequent paired *t*-tests revealed significant mean increase in HP from rest to task in the WL Group at the pre-intervention Visit ($p < 0.003$) and the post-intervention Visit ($p < 0.03$). Subsequent paired *t*-tests revealed significant mean increase in HP from rest to task in the MMA Group at both the pre-intervention Visit ($p < 0.001$) and the post-intervention Visit ($p < 0.001$).

For RSA, there were no significant effects of Visit, Condition, or Group (ps > 0.47). There were no interactions found between Visit, Condition, and/or Group (ps > 0.46). Subsequent paired *t*-tests revealed no significant mean change in RSA from rest to task in the WL Group at either Visit (ps > 0.85). Subsequent paired *t*-tests also revealed no significant mean change in RSA from rest to task in the MMA Group at either Visit (ps > 0.53).

I also assessed for mean changes from rest to task in HP and RSA at the follow-up Visit. For HP at this Visit, there was a significant decrease in HP in the WL Group ($p < 0.02$) and the MMA Group ($p < 0.001$). For RSA at this Visit, there was no significant change in RSA in the WL Group ($p > 0.12$; See Figure 3a), but there was a significant decrease in RSA in the MMA Group ($p < 0.02$; See Figure 3b).

Relation between parent and adolescent self-report. The second exploratory analysis examined the relation between parent- and adolescent self-reports of executive function in all participants. This analysis was completed to thoughtfully interpret one of my primary research questions investigating how executive function may improve over the course of MMA. With research suggesting multiple informants often are in disagreement with each other (De Los Reyes, Thomas, Goodman, & Kundey, 2013), I sought to investigate how parent- and adolescent self-reports differed and thus make an informed decision as to which report to interpret. Pearson correlations were used to relate parent- and adolescent self-reports at Time 1 for the BRIEF.

To examine the relation between parent- and adolescent self-reports of executive function, Pearson correlations were conducted between parent-reported BRIEF subscale and index scores and adolescent self-reported BRIEF subscale and index scores at Visit 1. The subscale of inhibit was significantly and positively correlated between parent- and adolescent self-reports ($r=.63$, $p < 0.006$). Additionally, the subscale of working memory was significantly and positively correlated between parent- and adolescent self-reports ($r=.49$, $p < 0.05$). All other subscales and indexes were not significantly correlated ($ps > 0.13$).

Predictive utility of resting RSA. I was also interested in the predictive utility of resting RSA in predicting executive function in the sample and hypothesized higher resting RSA at pre-intervention would be related to better executive function after MMA, after controlling for post-intervention levels of resting RSA. If higher resting RSA at pre-intervention is related to better executive function after MMA, this would provide

evidence that RSA can be used as a tool predicting improvements in the executive function challenges that these youth have. To examine whether resting RSA at Visit 1 could be used as a predictive measure relating to executive function after MMA, partial correlations were conducted with Visit 1 resting RSA and Visit 2 measures of EF (parent-reported BRIEF) controlling for Visit 2 resting RSA.

In examining whether resting RSA at Visit 1 could be used as a predictive measure relating to executive function after MMA, partial correlations were conducted with Visit 1 resting RSA and Visit 2 measures of EF (parent-reported BRIEF) controlling for Visit 2 resting RSA. When performing this analysis with all participants, significant negative correlations emerged for the parent-reported BRIEF subscale of initiate (r=.50, $p < 0.03$) and working memory (r=.46, $p < 0.05$), suggesting higher resting RSA at Visit 1 was associated with a better ability to initiate and better working memory at Visit 2. No other significant correlations emerged between resting RSA at Visit 1 and other parent-reported BRIEF subscales at Visit 2 ($p > 0.12$). When performing this analysis with MMA participants only, significant negative correlations emerged for the parent-reported BRIEF subscales of initiate (r=.65, $p < 0.01$), working memory (r=.68, $p < 0.008$), plan/organize (r=.57, $p < 0.03$), monitor (r=.56, $p < 0.04$) and the index of metacognition (r=60, $p < 0.03$), suggesting higher RSA was associated with better executive function in these domains at Visit 2. No other significant correlations emerged between resting RSA at Visit 1 and other parent-reported BRIEF subscales at Visit 2 ($p > 0.38$). When performing this analysis with WL participants only, no significant correlations emerged between resting RSA at Visit 1 and parent-reported BRIEF subscales at Visit 2 ($p > 0.27$).

Pre-intervention analyses. Additionally, I examined how resting HP and RSA at pre-intervention related to presenting problems in the child's profile, such as severity of ADHD symptoms and EF. I performed these analyses with all participants and predicted higher resting HP and RSA would be associated with less ADHD symptoms and better EF at pre-intervention. Pearson correlations assessed the associations between resting HP and RSA and behavioural parent- and adolescent self-reports of the Conners and BRIEF measures at Visit 1. To assess this same association while accounting for medication, separate partial correlations for resting HP and RSA were conducted with medication use as a covariate. I then carried out separate hierarchical regression analyses with resting HP or RSA at Visit 1 as the dependent variable. Medication use as a covariate was entered on the first step, followed by the Conners or BRIEF subscale on the second step.

Resting HP. Resting HP was marginally and negatively correlated with parent-reported Conners subscale of hyperactive/impulsive symptoms ($p < 0.07$). This suggests as HP increases, ADHD hyperactive/impulsive symptoms decrease. To account for medication, partial correlations were conducted with medication status as a covariate. After accounting for medication, HP was not related to any of the Conners subscales. Hierarchical regressions with medication status as a covariate were performed to determine whether HP predicted parent- or adolescent self-reports of the Conners after accounting for medication status. The effect of medication status was significant for the parent-reported Conners subscale of hyperactive impulsive symptoms ($p < 0.04$) and peer relations ($p < 0.02$). However, after accounting for medication, HP did not predict parent- or adolescent- self reported Conners scores (ps > 0.19).

Resting HP was not related to parent- and self-reported BRIEF subscales (*p*s > 0.13). To account for medication, partial correlations were conducted with medication status as a covariate. With these partial correlations, HP was significantly and positively correlated with the parent-reported BRIEF subscale of emotional control ($p < 0.05$). This suggests as HP increases, problems with emotional control increase. Additionally with these partial correlations, HP was marginally and positively correlated with the parent-reported BRIEF index of behaviour regulation ($p < 0.08$), meaning higher HP is related to increased problems with behaviour regulation. Hierarchical regressions with medication status as a covariate to determine whether RSA predicted parent- and adolescent self-reports of the BRIEF after accounting for medication status. The effect of medication status was significant for the parent-reported BRIEF subscales of inhibit ($p < 0.01$), shift ($p < 0.009$), emotional control ($p < 0.05$), and initiate ($p < 0.04$), as well as the behaviour regulation index ($p < 0.006$). However, after accounting for medication, HP did not predict self- or parent- reported BRIEF scores (*p*s > 0.16).

Resting RSA. Resting RSA was significantly and negatively correlated with parent-reported Conners subscale of hyperactive/impulsive symptoms ($p < 0.03$). Here, higher RSA is related to less ADHD hyperactive/impulsive symptoms. To account for medication, partial correlations were conducted with medication status as a covariate. After accounting for medication, RSA was not related to any of the Conners subscales. Hierarchical regressions with medication status as a covariate were performed to determine whether RSA still predicted parent- and adolescent self-reports of the Conners after accounting for medication status. The effect of medication status was significant for

the parent-reported Conners subscale of hyperactive impulsive symptoms ($p < 0.04$) and peer relations ($p < 0.02$). However, after accounting for medication, RSA did not predict parent-reported Conners scores (ps > 0.09).

Resting RSA was marginally and negatively correlated with parent-reported BRIEF subscales of inhibit ($p < 0.08$) and plan/organize ($p < 0.06$), suggesting higher RSA is related to a greater ability to inhibit and plan/organize. Resting RSA was significantly and negatively correlated with parent-reported BRIEF subscales of initiate ($p < 0.002$) and monitor ($p < 0.03$), suggesting higher RSA is related to a greater ability to initiate and monitor. Resting RSA was marginally and negatively correlated with the self-reported BRIEF subscale of shift ($p < 0.06$). Here, as RSA increases, shift problem scores decrease. Resting RSA was significantly and negatively correlated with the self-reported BRIEF subscales of emotional control ($p < 0.04$), working memory ($p < 0.05$) and the index of behaviour regulation ($p < 0.05$). These results suggest higher RSA is related to better emotional control, working memory, and behaviour regulation. To account for medication, partial correlations were conducted with medication status as a covariate. After accounting for medication, RSA was not significantly related to any of the behavioural parent- and adolescent self-reports. Hierarchical regressions with medication status as a covariate were conducted to determine whether RSA still predicted behavioural parent- and adolescent self- reports, after accounting for medication status. The effect of medication status was significant for the parent-reported BRIEF subscales of inhibit ($p < 0.01$), shift ($p < 0.009$), emotional control ($p < 0.05$), and initiate ($p < 0.04$), as well as the behaviour regulation index ($p < 0.006$). Even after a significant effect

of medication status, RSA still predicted parent-reported BRIEF initiate subscale scores (β=-4.25, SE= 1.70, $p < 0.02$). In this case, medication accounted for 19% of the variance and RSA accounted for 37% of the variance in initiate scores. After accounting for medication, RSA did not predict any other parent or adolescent self- reported BRIEF scores (ps > 0.12).

ADHD subgrouping. I was interested in how HP or RSA differed depending on ADHD diagnosis. ADHD subgroups were classified by exceeding the *T*-score clinical cutoff of 70 in the Conners subscales of inattentive and/or hyperactive/impulsive. Combined subtype consists of participants who exceeded the clinical cutoff *T*-scores for both subscales (inattentive and H/I). When participants exceeded both clinical cutoff *T*-scores, they were included in the combined subtype and eliminated from the individual subtype. ADHD subgrouping was based on the Conners. The Conners was utilized in the present study to help parallel findings with a previous MMA investigation by Haydicky et al. (2012) that also used the Conners to subgroup MMA and WL participants.

Independent *t*-tests were conducted within each ADHD subgroup to determine whether resting HP or RSA at Visit 1 differed (elevated *T*-score for that type of ADHD vs. non-elevated score for that type of ADHD) in all participants.

Additionally, a one-way ANOVA was conducted between the four ADHD subgroups (no diagnosis, inattentive, H/I, and combined) to determine whether resting HP or RSA at Visit 1 differed in all participants. Subsequent independent *t*-tests were performed to explore whether resting HP or RSA at Visit 1 differed between subgroups.

Within ADHD subgroups: Differences in autonomic measures at Visit 1.

Independent t-tests were conducted within each ADHD subgroup to determine whether resting HP and RSA at Visit 1 differed (elevated *T*-score for that type of ADHD vs. non-elevated score for that type of ADHD) in all participants. No differences were found within any Conners subscale for HP (*p*s > 0.25). For RSA, the independent *t*-test was significant for the inattentive subscale ($t(22)=-2.01$, $p < 0.04$; See Figure 4). Specifically, higher levels of resting RSA were observed in the subgroup with clinically elevated levels of inattentive symptoms ($n=7$, $M=7.32$, $SD=1.12$) than the subgroup without clinically elevated levels of inattentive symptoms ($n=17$, $M=6.21$, $SD=1.14$) at Visit 1. No significant difference ($t(22)=-0.095$, $p > 0.93$; See Figure 4) was found for participants with elevated H/I symptoms ($n=2$, $M=6.61$, $SD=0.067$) compared to those without elevated H/I symptoms ($n=22$, $M=6.52$, $SD=1.28$). A marginal difference ($t(22)=1.957$, $p < 0.06$; See Figure 4) was observed for the combined type. Specifically, lower levels of RSA were found in the subgroup with clinically elevated levels of both inattentive and H/I symptoms ($n=9$, $M=5.92$, $SD=1.53$) than Group without clinically elevated levels of both symptoms ($n=15$, $M=6.88$, $SD=0.87$).

Between ADHD subgroups: Differences in autonomic measures at Visit 1.

Autonomic values for the ADHD subgroups for all participants, as classified by exceeding the *T*-score clinical cutoff of 70 in the Conners subscales of inattentive and/or hyperactive/impulsive, are outlined in Table 5. A one-way ANOVA was conducted between the four ADHD subgroups (no diagnosis, inattentive, H/I, and combined) to determine ether resting HP and RSA at Visit 1 differed in all participants. No significant

differences were found between the ADHD subgroups for both HP and RSA (ps > 0.16). Subsequent independent t-tests were performed to explore whether HP and RSA at Visit 1 differed between subgroups. RSA was found to be marginally greater in the inattentive subgroup than the combined subgroup ($t(14)=2.01$, $p < 0.06$). HP and RSA did not significantly differ between any of the other subgroups (ps > 0.10).

Discussion

The present study examined the influence of Integra Mindfulness Martial Arts (MMA) on psychophysiological correlates of self-regulation and measures of executive function in adolescent males with LDs and co-occurring self-regulatory challenges. While extensive research on youth with LDs has identified difficulties with social interactions, emotion and behaviour regulation, and executive function, this group has been suggested to be one of the most ignored in terms of mental health services and psychological research into therapeutic techniques (Reed, 1997). Specifically, few treatments have been modified for youth with LDs or other information processing difficulties (Moree & Davis 2010). MMA is a group treatment designed specifically for adolescents with LDs and co-occurring self-regulation challenges. Previous research on MMA suggests youth exhibited increased self-awareness and behaviour regulation and improved emotional well-being, self-understanding, communication, and peer relations after intervention (Milligan et al., 2010; Milligan et al., 2015). Compared to a group of waitlist controls, Haydicky et al. (2012) found youth with LDs and ADHD exhibited decreased externalizing behaviour, and youth with LDs and anxiety reported decreased anxiety at the end of treatment, suggesting possible improvements in underlying self-regulation. While this research

suggests change at a behavioural level, we know little about how MMA may alter psychophysiological correlates of self-regulation that are important in indexing individual differences in the regulation of emotions and behaviours. If psychophysiological correlates of self-regulation are altered in response to MMA, this would further establish both the effectiveness of the intervention and the sensitivity of the psychophysiological measure. Specifically, this evidence would support the ability of the intervention to target self-regulation and would suggest the psychophysiological measure is malleable with intervention.

Change Across Time: Autonomic Measures

My primary research goal was to investigate change across time for autonomic measures, namely heart period (HP) and respiratory sinus arrhythmia (RSA). With previous research suggesting MMA targets self-regulation, it was predicted that post-intervention, the MMA group would have increased resting HP and RSA, while the wait-list controls would show no change.

Change in heart period. I observed a decrease in HP in the WL group and an increase in HP in the MMA group. While the Group by Visit interaction was only marginally significant, the direction of change within the MMA group was consistent with my predictions. It is possible that these results did not reach statistical significance due to low power, given the small sample size. Nevertheless, the results are promising showing increased HP at the post-intervention visit in the group participating in MMA. Consistent with my predictions, an increase in HP after intervention may reflect less behavioural inhibition, anxiety, and emotion dysregulation that is characteristic of a high

heart rate in the literature (Kagan et al., 1988; Schmidt & Fox, 1994). Contrary to this, a pattern that has also been observed in the literature concerning HP suggests that higher HP is associated with disinhibition. This pattern has been found in samples of males with high rates of aggression and externalizing symptoms (Raine, 1996). While research has suggested that adolescents with LDs report higher levels of externalizing behaviours, such as aggression and risk-taking (McNamara et al., 2008, McNamara & Willoughby, 2010), according to the MINI conducted at the pre-intervention visit, the sample presented with anxiety or problems of behaviour inhibition, rather than disinhibition. Thus, these youth presented with problems in emotion regulation, and perhaps the trend of increased HP in response to MMA suggests the intervention may be tapping emotion regulation processes captured with this measure. In addition to the therapy components of MMA, HP may have increased due to an increase in physical exercise during the course of intervention, as there has been a well documented finding of decreased HR after interventions consisting of physical exercise and yoga specifically (Ross & Thomas, 2010). It will be important for future research to address this possibility by investigating change in HP with an exercise only control group compared to MMA.

The trend of malleability that was observed is important as it may highlight how cardiac control may be altered with MMA. As discussed, HP is the result of the competitive innervation of the heart by the sympathetic and parasympathetic nervous systems, with lower HP being an index of greater sympathetic activity (Cacioppo et al. 1994; Kagan et al., 1988). The higher HP that was observed suggests more activity of the vagus nerve, the primary parasympathetic branch, which works to slow the heart. This

increased parasympathetic activity highlights a low arousal state that is particularly important for these youth, with their strong patterns of distress, anxiety, etc.

Change in respiratory sinus arrhythmia. I observed a slight decrease in RSA in the WL group, and an increase in the MMA group. While these differences across time were not statistically significant, the direction of change within the MMA group was consistent with my predictions. It is possible that these results did not reach statistical significance due to low power, given the small sample size. Nevertheless, the results are promising showing increased RSA at the post-intervention visit in the group participating in MMA. This trend adds to the literature on exercise therapy and its effects on measures of heart rate variability (see Routledge et al., 2010). Additionally, increased RSA is consistent with studies on yoga (Friis & Sollers, 2012; Khattab et al., 2007; Ross & Thomas, 2010). The trend of increased RSA also adds to the literature on the effects of mindfulness on HRV indices, including RSA (Bhatnager et al., 2013; Krygier et al., 2013; Tang et al., 2009; Wheeler et al., 2014). This finding suggests MMA may positively influence autonomic adaptability, improving self-regulation indirectly. While the exact mechanisms underlying the modification of RSA with exercise in general are unknown, some theories do attempt to explain this association.

One hypothesis outlined in Routledge et al. (2010) suggests exercise modulates cardiac autonomic control by lessening sympathetic influence and enhancing parasympathetic or vagal tone. This shift toward greater vagal modulation is consistent with a growing body of research evidence supporting that exercise, and yoga in particular, may improve mental health through down-regulation of the sympathetic nervous system

(see Ross & Thomas, 2010), which would effect the release of catecholamines such as epinephrine and norepinephrine that lead to the mobilization of energy required to confront stressors through the classic ‘‘fight or flight’’ syndrome. Yoga has been shown to significantly lower plasma norepinephrine and epinephrine (Selvamurthy et al., 1998).

However, the difference in change in RSA between MMA and WL groups cannot solely be attributed to the physical aspects of MMA, as 4 out of the 5 WL participants reported taking part in recreational physical fitness activities. Accordingly, other components of MMA may have also contributed to the increase in RSA in the MMA group only. Mindfulness practices within MMA cultivate mindful attention, along with core concepts such as impermanence, awareness and acceptance of the present moment, non-judgmental observation, and letting go. These concepts enable appropriate engagement with stressors, which may have associated autonomic responses. With this relaxation and present-focus, parasympathetic activity is activated and after practice of this engagement, youth may learn to use these tools regularly. Change in RSA resulting from mindfulness practices supports the premise that mindfulness may improve self-regulatory mechanisms such as attention and emotion processing (Peressutti, Martin-Gonzalez, Garcia-Manso, & Mesa, 2012), and control over heart rate (Delizonna, Williams, & Langer, 2009). Cognitive therapy within MMA may have contributed to the increase in RSA with its emphasis on viewing negative feelings and events as temporary. This shift may have helped youth decrease their anxiety and anticipation of failure and distress, resulting in a reduced sympathetic drive.

While past research has investigated the relation between RSA and physical exercise and yoga, the present study is the first to examine the association between RSA and martial arts. Martial arts emphasizes self-control, discipline, and inhibitory control. These core components enable youth to develop greater self-regulation capacities, which may partly explain the observed increase in this psychophysiological correlate of self-regulation. Youth may have learned to inhibit prepotent avoidance strategies by practicing the discipline learned through the martial arts training. This self-control may be manifesting as greater RSA after intervention.

While it is possible to speculate explanations as to why this psychophysiological index self-regulation did slightly increase after MMA, we are unable to disentangle the various components of MMA to identify the active component of treatment contributing to this improvement.

Alternative explanations for HR and RSA findings. Alternatively, perhaps there are other explanations for why there were no significant changes in HP or RSA in the MMA group, other than the small sample size. One possibility could be that the intervention may not be individualized enough to address the self-regulation challenges of such a heterogeneous sample. The sample consisted of individuals with LDs comorbid with ADHD (both inattentive and hyperactive/impulsive) and anxiety and while in both disorders, interventions targeting relaxation could calm the nervous system and improve self-regulation, individuals with different comorbid disorders may respond differently. This could be why the change in HP or RSA was not large in size and not significant. If

this is the case, we would need to disentangle the factors that may be responsible for treatment response and alter treatment plans based on this information.

Additionally, perhaps the exercise within MMA is not the type of physical activity that previous studies have found to increase RSA. The review by Routledge et al. (2010) found increases in RSA with exercise therapy that was mainly aerobic. While yoga and martial arts do involve aerobic exercise, these practices also involve anaerobic exercise, which may not impact autonomic nervous system function as extensively as a strict cardiovascular aerobic exercise regime. Although studies have reported higher parasympathetic activity among those who were physically trained and fit compared to those who were not (Goldsmith, Bigger, Steinman, & Fleiss, 1992), it may be the case that even after 20 weeks of MMA, physical fitness in these youth didn't improve enough to observe significant change. Shephard and Balady (1999) warn as with pharmacological therapy, exercise requires a prescription with a consideration of appropriate dosage. Specifically, they suggest gains may require exercising at least three times per week. MMA may be more about mindful attention and self-awareness, rather than vigorous physical activity. Perhaps this type of intervention with this population takes more than 20 weeks before the self-awareness and thus, self-regulation internalizes with these youth. To examine this further, participant recruitment could extend to youth enrolled in the advanced MMA program, which is the program following the beginner MMA program. This would allow an investigation of whether a longer course of MMA is required to see physiological change.

While not statistically significant, the increase in RSA post intervention observed in the present study is similar to previous studies investigating the effects of mindfulness on HRV indices, including RSA. Significantly increased RSA has been found after meditation and mindfulness training (Tang et al., 2009), however other studies have not found significant increases in RSA. Specifically, other investigations have revealed significant improvements in the phenotype of interest (such as depression, wellbeing, etc.) after mindfulness-based interventions, however no significant increases in HRV indices that were hypothesized to correlate with the phenotype (Bhatnager et al., 2013; Krygier et al., 2013; Wheeler et al., 2014). While the investigation by Tang et al. (2009) was only 5 days in length, these mindfulness-based interventions that did not find significant increases in RSA were shorter in length than MMA (ranging from 10 days to 8-weeks), adding merit to the suggestion that mindfulness interventions may take longer to impact physiological systems.

Lastly, recent research has suggested that the effect of mindfulness meditation on psychophysiological processes might depend on the type and duration of the meditation (Britton, Lindahl, Cahn, Davis, & Goldman, 2014). Based on this notion, Lumma, Kok, and Singer (2015) investigated how training in different mindfulness practices would alter HR and RSA over time. This investigation found increased HR and decreased RSA over time with mindfulness practices such as loving-kindness meditation, but found no changes in HR or RSA over time with breathing meditation. These findings are contrary to the hypothesis that with training of mindfulness mediation in general, activation of parasympathetic nervous would increase and thus RSA would be higher.

These differential findings between loving-kindness meditation and breathing meditation may be important for the present study because youth enrolled in MMA participate in both types of meditation. Within MMA, loving-kindness meditation is practiced during sitting meditation where the aim is to develop a loving acceptance of oneself and overcome feelings of self-doubt, and the mindful moment is a non-striving breathing exercise, similar to the breathing meditation in the Lumma et al. (2015) study. Loving-kindness mediation is a striving action and involves complex processes such as the generation of mental imagery and positive affect, focusing on complex objects of attention including emotions and thoughts. Thus, Lumma et al. (2015) posit that gaining expertise in this type of meditation leads to an increase in the activation of the sympathetic nervous system, whereas practicing breathing meditation does not lead to any changes in cardiac responses. Loving-kindness meditation may be considered more of a demanding mental exercise that uses more attentional and cognitive resources required for a better mastery of the task.

While in this study, HR and RSA were recorded while participants were actually performing these meditation practices and the participants in the present study were at rest, this is nevertheless an interesting and perhaps relevant phenomenon. This is limited to speculation, as we cannot speculate on the mental activity of our participants during the resting state, but it possible they were employing the tools that they had learned during MMA to cope with the possible frustration of sitting still for five minutes – one of which is loving-kindness meditation. Accordingly, these participants may have been increasingly wakeful and alert, which Amihai and Kozkevnikov (2014) suggest is part of

the active process of loving-kindness mediation, which is an arousal state activating the sympathetic nervous system. While this is strictly speculation, to our knowledge there is no published study on the long-term effects of resting autonomic activity with training in striving vs. non-striving meditation.

Change Across Time: Executive Function

I was also interested in examining how reports of executive functioning changed from pre- to post-intervention. I predicted that problem scores on the BRIEF would decrease in the MMA group, and the WL group would show no change. Before interpreting the observed trends, a note on how perceptions of executive function may differ between parents and youth themselves. Previous reports have suggested that youth may have very different perceptions than their parents about a variety of their own experiences and behaviours, including stressful events (Lewis, Siegel & Lewis, 1984) and somatic complaints (Taylor, Szatmari, Boyle, & Offord, 1996). Additionally, research cautions against drawing strong inferences from multiple informants, which are often in disagreement with each other (De Los Reyes et al., 2013). To this end, I investigated the relation between parent- and self-reports of executive function, as assessed through the BRIEF. In the sample, the majority of reports of executive function were not correlated between parent- and self-report, with the exception of the subscales of inhibit and working memory. While we are aware that parents can be uninformed of their child's emotional and behavioural responses to a variety of events, we are also aware of the information processing deficits present in those with learning disabilities and ADHD that may impact the completion of self-report measures (Heath & Glen, 2005; Owens,

Goldfine, Evangelista, Hoza, & Kaiser, 2007), and thus, my interpretation of change in executive function in response to MMA will be based on parent-reports.

According to parent-reports, youth in both the WL and MMA groups improved on their ability to appropriately modulate or regulate emotion at the post-intervention visit, as compared to the pre-intervention visit. While I did not expect this effect of visit in the WL group, 2 out of these 5 WL participants were currently enrolled in other forms of psychotherapy, and 4 out of these 5 WL participants reported taking part in recreational physical fitness activities, which may be contributing to these improvements. However, this improvement in emotional control observed in the MMA group is consistent with my predictions. Specifically, decreased problem scores on this BRIEF subscale suggests these youth can appropriately modulate and control emotional responses without sudden and/or frequent mood changes. This is especially pertinent, as research has suggested that youth with LDs have worse emotion regulation than children without LDs (Bauminger & Kimhi-Kind, 2008) and have been said to be at higher risk for emotional distress, suicide, attempts and violence (Svetaz, Ireland, & Blum, 2000). The mindfulness component of MMA is suggested to target emotional control through purposeful attention. Purposeful attention to the present moment allows these youth to attend to the conditions (feelings, bodily sensations, etc.) that give rise to maladaptive emotional control. Recognizing current thoughts, feelings, and emotions can help these youth choose how to react to challenges, rather than reacting in an automatic, impulsive, and possibly inappropriate manner.

This improvement on emotional control adds to the current literature on the effect of mindfulness on emotional and behavioural self-regulation in youth. Research on mindfulness training with youth has found reductions in anxiety symptoms (Semple, Lee, Rosa, & Miller, 2010; Semple, Reid, & Miller 2005), and improvements in behavioural regulation (Flook et al., 2010). In youth with LDs, one study found reductions in anxiety and improvements in social skills (Beauchemin, Hutchins, & Patterson, 2008). Perhaps this improvement in emotional control is an outcome of the mindfulness training, as research suggests deliberate and nonjudgmental observation of anxiety-related sensations, without attempts to escape them, can lead to decreased emotional reactivity (Kabat-Zinn et al., 1992).

The specific executive function improvements we observed in the MMA group only were related to the domains of initiating, planning and organizing, and an index of metacognition.

Initiate. The improvement in the initiate subscale suggests that after MMA, these youth are better able to independently generating ideas, responses, or problem-solving strategies. This is especially crucial for youth with LDs and mental health challenges who often display a strong pattern of EA. As discussed, strong avoidance behaviour is common as a result of a repeated pattern of failure. To cope with strong negative emotions, these youth avoid thoughts and emotions associated with distress or engage in activities that provide short-term relief from discomfort.

MMA targets this avoidance directly by improving self-awareness with mindfulness training and thereby becoming present with all experiences. Individuals with

LDs often avoid challenging work including addressing mental health issues, which suggests these youth are generally low on initiate to start. Key mindfulness practices such as bringing attention to breath and the present moment may encourage this skill of initiating (Flook et al., 2010). When thoughts begin to drift away from the present moment, the ability to independently bring their breath and mindset into the present moment is an example of the ability to initiate. Conversely, giving up on the task of bringing attention to breath and the present moment may be considered avoidance of a difficult task. Along with the mindfulness component, there is a strong focus on behaviour activation and goal attainment within the program. Specifically, youth are motivated to earn points towards achieving the next belt level in their martial arts training. This may be unique for youth with LDs as research proposes this population participates in less recreational physical activity (Alley, 1980), suggesting this may be a novel type of motivation where they are truly involving themselves in a physical activity that they enjoy, i.e.: martial arts. This finding helps quantify the qualitative exploration of how MMA addresses self-regulation challenges where Milligan et al. (2015) found that 6 out of 7 participants liked the martial arts component of the program and having the opportunity to be physically active and engage in something that was of high interest to them. This focus on goal attainment within MMA may be improving their ability to initiate in other aspects of their lives, as reflected in their improvement within this domain of executive function.

Plan and organize. The improvement in planning and organizing suggests that after MMA, these youth are better at managing current and future-oriented task demands.

The improvement in planning specifically implies an increased ability to anticipate future events, set goals, and develop appropriate steps towards attaining that goal, while the improvement in organizing indicates an increased ability to appreciate key concepts while learning and/or communicating information. This result is fundamental for youth with LDs who struggle in a learning environment, and equally as important for the present sample whose LD is comorbid with ADHD and therefore struggle with attention. Previous literature has suggested weaknesses in planning and organizing commonly present in youths with LDs and ADHD (Mattison & Mayes 2010; Pennington & Ozonoff, 1996). For these youth, organizing incoming information in the classroom is a challenge as is sequentially planning steps towards completion of a task, homework assignment, etc..

MMA targets this ability to plan and organize through its mindfulness and yoga components. Mindfulness focuses on awareness of the present, which may help these youth develop better self-control and attention. Self-control is imperative when strategically determining the most effective steps toward goal attainment. Without self-control, youth may reflexively resort to less effective means of goal attainment. Additionally those with attention deficits could lose focus and disengage from goal attainment altogether. On the other hand, attention helps when learning and understanding main ideas in presentations and/or written material. Yoga, which integrates body with mind, can help youth with their attention. Improved attention may provide a foundation for supporting improvements in planning and organizing. This finding adds to the literature on yoga which has previously found improvements in attention and other

symptoms of ADHD (Haffner, Roos, Goldsteiner, Parzer, & Resch, 2006; Jensen & Kenny, 2004; Peck, 2005; Steiner, Sidhu, Pop, Frenette, & Perrin, 2012).

Metacognition. The improvement in the metacognition index suggests that after MMA, these youth are better able to initiate, plan, organize, self-monitor and sustain working memory. These youth with LDs, and those with LDs and ADHD may experience difficulties problem solving within a school environment as well as during social interaction, where the ability to self-manage and self-monitor would be essential. These abilities to self-manage and self-monitor require attention to internal and external conditions during task performance. Specifically, working memory is an area of executive function that has been found to be poor in youth with LDs and ADHD (Mattison & Mayes, 2010; Pennington & Ozonoff, 1996).

Various components of MMA target these abilities. As discussed, mindfulness and yoga can improve attention, which is imperative to metacognition. Mindfulness practices have been found to improve metacognition in adults (Teasdale, Moore, Hayhurst, Pope, Williams, & Segal, 2002) and children (Flook et al., 2010). Additionally, the cognitive therapy within MMA specifically addresses negative self-talk. During difficult tasks where self-monitoring is crucial, whether it be homework or during interpersonal interactions, these youth engage in negative self-talk that would hinder productivity. During MMA, cognitive therapy teaches these youth how to view and appropriately respond to emotions of frustration, etc. This lesson helps them cope with negative self-talk and move towards acceptance by using mantras such as “it will change”. With

mindfulness, yoga, and cognitive therapy, metacognition was improved within the context of problem solving in a variety of contexts.

How exercise may improve executive function and mental health. Findings that suggest exercise, and specifically an MMA intervention can improve certain aspects of executive functioning in youth adds to this body of literature (see Best, 2010 for a review). While I have discussed how MMA may target the specific aspects of executive function that I observed improvements within, the mechanisms explaining how exercise improves executive functioning and overall mental health deserves mention. Best (2010) considers general pathways whereby exercise can improve executive functioning. The first pathway highlights the cognitive demands inherent in the structure of goal-directed and engaging exercise. This pathway suggests that many forms of exercise are cognitively engaging activities, and martial arts would be no different. Specifically with the practice of martial arts, self-control is of the utmost importance and this would engage cognitive functions such as inhibition and impulse control. Thus, perhaps cognitive skills acquired during the practice of martial arts transfers to how executive function is employed during everyday tasks. The second pathway stresses the cognitive engagement required to execute the complex motor movements. This pathway suggests the execution of complex motor movements also recruits neural circuitry associated with executive functioning. Diamond (2000) proposed a close neural link between, and co-activation of, the cerebellum, important for complex and coordinated movement, and dorso-lateral PFC (DL-PFC), critical for executive functioning. Diamond (2009) also argued that the brain operates on a global-default mode and that both cognitive and motor activities that rely on

non-automatic and selective processing require the effortful overriding of that default. As an example of this, Diamond explains the execution of bimanual coordination tasks, where the individual does different things with each hand simultaneously. This is particularly applicable for the practice of mixed martial arts within MMA, where jabs and crosses are simultaneously performed. These complex movements appear to be inherently cognitively engaging, and this could contribute to the observed improvements in executive functioning. Finally, the third pathway highlights not only the general physiological changes to the body in response to exercise (e.g., increased blood flow) but also specific changes in the brain (see Best, 2010). This body of literature suggests acute exercise promotes immediate neurochemical responses that may enhance cognitive performance, and chronic exercise induces morphological changes to brain regions critical to learning. Best (2010) highlights the importance of exercise for populations such as those with ADHD and/or learning disabilities, where deficits in executive function are paramount.

There are also psychological theories that attempt to explain the observed improvements in mental health in response to exercise. The psychological mechanism that may explain the present findings is the mastery hypothesis, which suggests that command of a challenging pursuit such as exercise trains a sense of independence and success outside of exercise settings. This hypothesis postulates that as exercisers become more confident and gain mastery of their physical skills, they may take this feeling of control and success into their everyday lives (Hughes, 1984; Paluska & Schwenk, 2000). The experience of mastery improves the individual's self-confidence or self-efficacy,

which in turn improves their ability to tackle their problems (Bandura, 1977). This proposed theory can help to disentangle the process by which the practice of martial arts and yoga can in turn improve executive function in the everyday lives of these youth. Consistent with the qualitative exploration of MMA by Milligan et al. (2015), these youth have a desire to better themselves and develop mastery. For these youth, the idea of mastery was extended to development of mastery with schoolwork and fitness, in addition to mastery in the practice of martial arts. Milligan et al. (2015) found that working toward mastery was associated with a sense of pride, and that development of mastery and pride were key motivators of youth engagement, which has been positively related to treatment retention (Smith, Duffee, Steinke, Huang, & Larkin, 2008). The development of mastery may stem from the cognitive therapy component of MMA where Dweck's (2006) growth mindset is fostered. This belief or mindset that change is possible and negative situations are not fixed sets the stage for the development of goals related to mastery. Importantly for youth with LDs, Elliot and Church (1997) have applied the concept of mastery to achievement motivation, stressing the importance of mastery- and performance-related goals. Milligan et al. (2015) found that youth in MMA displayed both mastery and performance related goals. The youth declared a desire to 'become excellent' at martial arts, which is consistent with mastery goals, where the focus is on the development of competence. Youth also shared a desire to achieve a higher belt level, which is consistent with performance-oriented goals, or attaining a level of performance that will be viewed positively by others. Importantly, the development of mastery and sense of control over positive outcomes that may result from mastery over their physical body in the context of

exercise has been associated with later physical and psychological health in adulthood (Conger, Williams, Little, Masyn, & Shebloski, 2009).

Exploratory Analysis

Change in autonomic measures from resting to task. Heart period decreased from resting to task in both groups at both time points, suggesting that independent of MMA, these participants demonstrated sympathetic drive in response to the selective attention task. This is consistent with research that suggests that increased heart rate is associated with cognitive arousal and mental effort (Critchley, Eccles, & Garfinkel, 2013).

RSA decreased from resting to task only at the follow-up visit and only in the MMA group. This difference between the WL and MMA group may reflect the difficulty the regulatory disordered adolescent has in regulating the autonomic nervous system to support a behavioural state required for attention and information processing during this selective attention task. State changes in RSA during attention-demanding tasks may index mental effort and attention (Seuss et al., 1994). This ability to engage and disengage the "vagal brake" when faced with a challenge is adaptive and indicative of cognitive control (Porges, 2007). This finding mirrors work by Napoli, Krech, and Holley (2005) which found that a 24-week mindfulness based program with yoga led to improved selective attention on performance of a computer task in elementary school children, compared to a control group.

With the present information, it is not possible to confidently determine why this decrease in RSA from rest to task was only found at the follow-up visit, it may be the

case that some aspects of the MMA intervention took more time to effect autonomic control in these youth. Perhaps it is only after incorporating the tools they learn in MMA, such as mindful attention and self-talk as well as self-control, discipline, and inhibitory control, into their everyday lives for a longer period of time, that we see this appropriate regulation of the autonomic nervous system during stress. Additionally, the follow-up visit took place when youth returned back to school, after a summer break. This timing may have also contributed to this significant finding at the follow-up visit, as youth had just returned back to their school routine where it is more necessary to regulate the stress of peers, schoolwork, etc. The significant decrease in RSA during the attention task represents an adaptive response to stress, which may be more prominent when practiced within the everyday school environment.

Predictive utility of resting RSA. In my investigation into the predictive utility of resting RSA at Visit 1 in predicting executive function at Visit 2, I hypothesized higher resting RSA at pre-intervention would be related to better executive function after MMA, after controlling for post-intervention levels of resting RSA. I found significant associations suggesting higher RSA at Visit 1 was related to better executive functioning at Visit 2 in the subscales of initiate and working memory but importantly, I found these same associations and others when restricting the analysis to MMA participants and no associations when restricting the analysis to WL participants.

The multiple significant relationships between these variables in the MMA group only may suggest higher RSA pre-intervention can help to predict improvements in executive function after intervention, or simply better executive function at separate visit

(specifically, after a 20 week intervention). It is possible that the associations within the MMA participants were driving the analysis with all participants. Alternatively, the lack of significance in the WL participants may have been due to the small number of participants in this group. Nevertheless, in the MMA group, I found Time 1 resting RSA was positively correlated with an improved ability to initiate, plan/organize, monitor as well as better working memory post-intervention. Because these correlations were salient while controlling for post-intervention levels of RSA, we can use this as evidence towards the predictive utility of resting RSA in indexing executive functioning after a 20-week intervention.

Pre-intervention analyses. At the pre-intervention visit, I predicted greater resting HP and RSA would be related to less ADHD symptoms on the parent-reported Conners, and better executive function, as reported by the BRIEF. Similar to my exploration of how executive function improved with MMA, for the current analyses I will be interpreting parent-reports of ADHD symptomology and executive function.

Contrary to my predictions, HP was positively correlated with problem scores of emotional control and behaviour regulation, suggesting as HP increased, problems with emotional control and behaviour increased according to parent-reported BRIEF. This result differs from literature that suggests high HR is associated with anxiety and emotion dysregulation (Schmidt & Fox, 1994), as the present results suggest that control of emotions and behaviour is better with high HR. This result may relate better with work by Raine and Jones (1987) who found that youth aged 7 to 15 with conduct disorder have lower resting HR levels. Raine and Venables (1984) sought to describe this phenomenon

with males 15 years of age with conduct disorder and suggested that lower HR may reflect a passive coping response that may serve to reduce emotional impact of punishment. This passive coping response is a withdrawal response that may prepare the individual for disengagement during a threatening situation. Low HR in pre- and mid-adolescence has been found to be predictive of criminality in young adulthood (Raine, Venables, & Williams, 1990). While there is no evidence to suggest the present sample may develop antisocial personality behaviour or go on to participate in criminal activity, it may be the case that this low HR may reflect a flat response to punishment, and thus increased problems with emotion control and behaviour. Parents may consequence youth for emotional outbursts or disruptive behaviour, but it may be the case that these youth are low on arousal and thus are not bothered by negative consequences. This pattern may serve to increase problems with regulation of emotions and behaviour.

RSA was negatively correlated with parent-reported hyperactive/impulsive symptoms, suggesting higher RSA was associated with less ADHD hyperactive/impulsive symptoms. This parallels research that has suggested children with ADHD displayed lower RSA compared to control children (Shibagaki & Furuya, 1997). This result suggests youth with problems with hyperactivity and impulsivity have lower parasympathetic activity at rest, which could be explained by the stimulation-seeking theory (Eysenck & Gudjonsson, 1989). This theory proposes a nervous system that is relatively insensitive to low levels of stimulation. Thus, individuals with this physiological state may be impulsive and sensation seeking because under conditions of relatively low stimulation they find themselves at a suboptimal level of arousal which is

aversive. Additionally, perhaps these behaviourally impulsive children are less fearful and uninhibited and thus, they may show less sympathetic activity at rest.

RSA was negatively correlated with parent-reported executive function subscales of initiate and monitor, suggesting higher RSA was associated with better ability to initiate and monitor. The ability to monitor consists of task-oriented monitoring, where an individual assesses their own progress during tasks to ensure appropriate attainment of the goal, and self-monitoring, where an individual keeps track of the effect their behaviour has on others. This finding is consistent with the notion that RSA may serve to index the functional capacity of a set of brain structures, such as the PFC, that support effective executive functioning including inhibitory control (Thayer at al., 2009). In order for to keep track of their behaviour during task or during social engagement, these youth must inhibit prepotent responses based on the information gathered during such monitoring. Prefrontal-subcortical inhibitory circuits that support flexibility and adaptability may be effective in youth with higher RSA, as seen through this increased monitoring ability, which mirrors previous research by Thayer and Lane (2000). Accordingly, high resting RSA has been linked to better performance on executive function tasks involving inhibitory control (see Thayer et al., 2009) as well as appropriate social engagement in children (Fox & Field, 1989), and social competence (Eisenberg, Fabes, Murgphy, Smith, & Karbon, 1995). The ability to initiate represents independently generating ideas, responses, and appropriate problem solving strategies. The relation between RSA and the ability to initiate was also salient after controlling for medication use. The ability to initiate depends on EF components such as cognitive flexibility involved in the planning

of an idea and response selection, which includes inhibiting other less appropriate responses such as problems-solving strategies. This finding is also consistent with previous models suggesting higher RSA may index a greater capacity of a set of brain structures, such as the PFC, which support such executive functions (Thayer et al., 2009).

ADHD subgrouping. The exploration into whether resting HP or RSA differed between individuals who exceeded the *T*-score clinical cutoff of 70 in the Conners subscales and those who did not suggested that resting RSA was higher in the subgroup with clinically elevated levels of inattentive symptoms compared to the subgroup without. This finding is contrary to previous research suggesting high RSA is associated with better attentional capacity (Seuss et al., 1994). This result may have been driven due to the unequal sample sizes in each subgroup. Alternatively, this finding could be explained with use of research by Miller, Wood, Lim, Ballow, and Hsu (2009) which investigated vagal activity in response to laboratory-induced emotional stress in individuals with asthma and found that vagal activity differed depending on depression scores. Those with high depression scores showed preponderance of vagal over sympathetic reactivity (deemed vagal bias) in their response to this emotional stress, while children without depressive symptoms showed greater preponderance of sympathetic (over vagal) reactivity. The pattern within the nondepressed children is considered the typical and adaptive response to emotional stress. In the present study, the sample of inattentive youth at rest seemed to display a similar pattern to the individuals with high depression scores. While individuals with depression and ADHD-inattentive type may not be the same in terms of phenotypic expression, these two disorders represent similar

dysregulation in self-regulatory capacities. Their research proposes dysregulated states may accompany a type of autonomic dysregulation, i.e.: vagal bias or hyper vagal tone during conditions of emotional stress. This phenomenon observed by Miller et al. (2009) may help us understand this hyper vagal tone in these youth with elevated ADHD-inattentive symptoms by suggesting that patterns of autonomic dysregulation may be atypical under different circumstances.

Medication as a Confounding Variable

Within the present sample, 25% of participants (*n*=6; 5 MMA, 1 WL) reported taking medication, such as antidepressants (specifically, SSRIs), stimulants, and anti-psychotics, at the pre-intervention visit. At this visit, I found that participants taking medication had lower resting RSA than those who were not taking medication. Lowered RSA in 5 of the MMA participants could also be contributing to the nonsignificant increase in RSA across time, as we assume medication use was consistent across visits.

This finding is consistent with previous research where antidepressants, including SSRIs, have been associated with lower RSA in individuals with depression (Licht, de Geus, Zitman, Hoogendijk, van Dyck, & Pennix, 2008) and anxiety (Licht et al., 2009). Interestingly, Litch et al. (2009) found the lower RSA seen in anxious participants survived adjustment for possible confounding factors as health indicators and lifestyle, but further adjustment for antidepressant use rendered all associations nonsignificant. However, cause and effect remain to be established. At this point, we do not know whether lower RSA is caused by antidepressant use and whether low RSA found in medicated individuals can be reversed when they cease medication use. Nevertheless, the

observed trends suggest an unfavourable association between antidepressant use and RSA. To our knowledge, the effect of stimulants (methylphenidate) and/or antispsychotics on respiratory sinus arrhythmia or heart rate variability in general has not been explicitly studied. However, a meta-analysis by Mick, McManus, and Goldberg (2013) revealed increased heart rate levels in individuals taking this medication type compared to placebo. This increase in heart rate could also be contributing to lower RSA but we cannot be sure, as past research has not explicitly linked stimulant and/or antipsychotic use to measures of heart rate variability. This combined research on the effects of antidepressant, stimulants, and/or antipsychotic use on heart rate and specifically, RSA may provide us with an alternative explanation for the nonsignificant increase in RSA across time, suggesting medication use may be suppressing physiological change in these youth. Moreover as noted in Licht et al. (2009), with clinical samples it is often difficult to gather large enough sample sizes to take into account potential confounders, such as medication use.

Medication use was also important in my secondary analyses where I looked at the relations between RSA and executive function at the pre-intervention visit. With hierarchical regressions, I found the effect of medication use significantly predicted parent-reported BRIEF scores on the inhibit, shift, emotional control, and initiate subscales, as well as the behaviour regulation index. For theses analyses, I accounted for this effect of medication before assessing whether RSA predicted these aspects of executive function but it is important to note variance due to medication use did contribute to measures of executive function in the present sample.

Limitations

There are several limitations that warrant discussion. First, given that pilot nature of this research, our sample size was small and likely underpowered to detect a significant change with respect to some of my research questions. This limitation is evident through the effect size, power, and sample size calculations. Table 4 outlines the observed effect sizes (Cohen's *d*) within each Group (WL and MMA) for HP and RSA across the two Visits. According to Cohen's guidelines on effect sizes (Cohen, 1977), the decrease in HP in the WL group was considered to be of medium strength and the increase in the MMA group was considered small to medium strength. For RSA, the decrease in the WL group and the increase in the MMA group were both considered to be small in strength (Cohen, 1977). Based on these effect sizes, I computed the power of this current study for the MMA Group only (n=15 pairs). With a Cohen's *d* of 0.39 for the change in HP, power was estimated at 0.29. With a Cohen's *d* of 0.16 for the change in RSA, power was estimated at 0.09. Based on the Cohen's *d* values in Table 4, sample size estimates were conducted for the MMA Group only to determine how many participants are needed to observe a significant mean change ($p < 0.05$) in either direction (two-tailed test), while achieving a level of statistical power of 0.8. With a Cohen's *d* of 0.39 for the change in HP and power set at 0.8, 54 participants would be required. With a Cohen's *d* of 0.16 for the change in RSA and power set at 0.8, 309 participants would be required. I also explored how many participants would be needed to observe a significant mean change ($p< 0.05$) in one implied direction (one-tailed test), while achieving a level of statistical power of 0.8. Specifically, I hypothesized that I would observe an increase in these

measures. With a Cohen's *d* of 0.39 for the change in HP and power set at 0.8, 43 participants would be required. With a Cohen's *d* of 0.16 for the change in RSA and power set at 0.8, 243 participants would be required. With this information, it is evident the present study did not have enough participants to observe significant change in these psychophysiological correlates of interest. For example, in a review by Routledge et al. (2010) where improvements in heart rate variability in response to exercise was investigated, sample sizes in studies were as high as 1284. Similarly, a review by Best (2010) where executive function improvements were investigated in response to exercise and in comparison with control groups, sample sizes in studies were as high as 177. If the sample size was larger, I could account for the multiple *t*-tests performed when investigating change in executive function with use of multiple correction strategies, such as the Bonferroni correction. Additionally, I could explore heterogeneity within the sample to investigate whether participants with different comorbidities responded to treatment differently.

Secondly, there are other aspects of the present study that while in concordance with a naturalistic treatment-as-usual study, may have impacted study results. First, while previous studies analyzing change in HRV selectively recruited drug-naïve participants (Chang et al., 2012; Lehofer et al., 1997; Moser et al., 1998), 25% of participants were using psychotropic medications. Although consistent with treatment as usual, it is possible that this may have influenced findings. Secondly, I only controlled for medication use at the pre-intervention visit only and thus I did not account for the possibility of change in medication type and/or dosage across the visits. With collection

of this information, an interesting future direction could involve a further investigation into how medication may impact autonomic activity. Additionally with information on changes in medication, it is possible to investigate how such a change in medication may work to impact treatment response. Lastly, a waitlist control design was used and therefore I could not compare autonomic or executive function measures of these youth to typically developing youth. To our knowledge, there is no study examining how autonomic measures differ between those with LDs and associated self-regulation challenges compared to typically developing youth, or youth with self-regulation challenges without an LD diagnosis. This investigation could help us further understand if having an LD diagnosis may exasperate the psychophysiological correlates related to poor self-regulation.

Lastly, in the present study we measured executive function with use of the parent-reported BRIEF rather than lab tests of executive function. Past research has supported the notion that BRIEF scores may not be correlated with performance-based executive function measures (Mahone & Hoffman, 2007) and therefore it may important for future investigations to look at improvements in performance-based executive function tasks in response to MMA for a clearer picture of this phenomenon. However, the BRIEF was a good functional measure for the present study as it assessed capacities that are particularly relevant to youth with LDs. For example, the BRIEF consists of subscales measuring the ability to initiate a plan to problem solve or to manage current and future-oriented task demands, which we have seen are particularly difficult for youth

with LDs and thus, it was important to measure if MMA may target and improve these aspects of executive function.

Conclusions

The present study provides preliminary evidence of the malleability of psychophysiological correlates of self-regulation and improvements in executive functioning in response to an MMA intervention in adolescent males with LDs and co-occurring self-regulatory challenges. The investigation into whether psychophysiological correlates of self-regulation are altered in response to MMA is important as it further establishes the effectiveness of the intervention, suggesting the intervention may be effectively targeting self-regulation capacities, and the sensitivity of the measure, suggesting it can be malleable with intervention.

The trend towards increased resting RSA and HP after intervention suggests exposure to MMA may increase self-regulatory capacities. The improvements in the ability to independently generate ideas or appropriate problem-solving strategies, in response to MMA, is especially crucial for these youth with their strong avoidance patterns. Additionally, the improved ability to plan and organize steps toward goal-directed behaviour is fundamental for these youth who struggle within a learning environment. This research is preliminary but findings suggest plasticity in self-regulatory systems, as well as how the environment may influence brain-behaviour relations.

Practically, this current research may be helpful in informing the delivery and structure of MMA. If we can observe improvements in phenotypic expression (improved

executive functioning), as well as improvements in the physiological processes that may underlie this phenotypic expression (higher resting RSA), we can target these specific physiological systems in a more concise manner. Specifically, my review of the literature suggests physical exercise (particularly aerobic exercise) has a vital role in increasing executive function, mental health, and the physiological systems regulating emotion and behaviour such as autonomic nervous system activity. Thus, incorporating an aerobic component to MMA may serve to increase these psychophysiological systems, and indirectly self-regulatory capacities, to a greater degree. My review of the literature also suggests that the mindfulness training component of MMA may take a longer period of time to impact autonomic functioning. This physiological system that is proposed to be the mechanism underlying the observed phenotypic change in the present study, as well as in previous investigations of MMA, may significantly increase after a longer duration of MMA. Thus, future investigations could include youth enrolled in the advanced MMA program to examine whether RSA significant increases after completion of both beginner and advanced MMA.

This research helps validate MMA as a promising intervention for youth with LDs and self-regulation challenges. However, future research with a larger sample size could further investigate whether is whether psychophysiological correlates of self-regulation, such as RSA, are significantly malleable in response to MMA.

Table 1. Sample MMA session: Everything changes, nothing stays the same

Session Component	**Component Description**
Brief BE Meditation	Sitting meditation
The Skill	Group discussion Will this change? Linked to previous lesson of fight, flight, or freeze Accepting things in the present moment
The Case	Chris' Ticking Clock (story demonstrating lesson linking to common challenges faced by group)
The Application	The skill "it will change" is practiced in context of BE meditation Mindful activity exercise
Yoga Warm-Up	Practice applying the skill "it will change" to discomfort experienced in the flow
Mixed Martial Arts	Practice flexibility in martial arts skills and need to change and adapt to new situations Martial arts skills: • jab, cross, push off back leg • jab, cross, push on kick pads • jab, cross with target and globes Teach group "sandwich feedback" and practice with training partner
Meeting with sensei, parent, and youth	Check practice Review healthy ways of being (note where improvements can be made) Help formulate goals or review goals (may relate to skill of that week or healthy ways of being)

(Adapted from Milligan et al., 2015, Integra & Badali, 2002).

Table 2. Two cohorts of data collection: Two-way contingency tables and independent samples *t*-tests on demographic variables and study measures

Demographics	**Cohort 1 vs. Cohort 2**
Age	$t(22)= .75, p>0.46$
BMI	$t(16)= -1.23, p>0.24$
Ethnicity	$\chi^2 (2, N=23) = 1.30, p>0.52$
Income	$\chi^2 (6, N=24) = 4.80, p>0.57$
Medication	$\chi^2 (1, N=23) = .29, p>0.59$
Handedness	$\chi^2 (1, N=22) = 1.02, p>0.31$
Therapy	$\chi^2 (2, N=24) = 5.77, p>0.56$
Fitness	$\chi^2 (2, N=24) = 5.56, p>0.06$
Autonomic @ Time 1	
HP	$t(22)= -.47, p>0.65$
RSA	$t(22)= -.45, p>0.66$
MINI diagnoses (Parent report)	
Major Depressive Episode	$\chi^2 (1, N=22) = 1.95, p>0.16$
Suicidality	$\chi^2 (1, N=10) = .48, p>0.49$
Dysthymia	None
Hypo-Manic Episode	$\chi^2 (1, N=22) = 2.25, p>0.13$
Anxiety	C2 only
Panic Disorder	$\chi^2 (1, N=22) = 2.25, p>0.13$
Agoraphobia	$\chi^2 (1, N=22) = 2.25, p>0.13$
Separation Anxiety Disorder	None
Social Phobia	$\chi^2 (1, N=22) = .58, p>0.45$
Specific Phobia	$\chi^2 (1, N=22) = .34, p>0.56$
Obsessive Compulsive Disorder	$\chi^2 (1, N=22) = .49, p>0.48$
Posttraumatic Stress Disorder	None
Alcohol Dependence Abuse	None

Substance Dependence Abuse	None
Tic Disorders	χ^2 (1, N=22) = .49, p>0.48
ADHD	C2 only
ADHD - Inattentive	χ^2 (1, N=22) = .11, p>0.75
ADHD – Hyperactive	χ^2 (1, N=22) = 2.40, p>0.12
ADHD – Total	χ^2 (1, N=22) = .11, p>0.75
Anorexia Nervosa	χ^2 (1, N=22) = .49, p>0.48
Bulimia Nervosa	None
Generalized Anxiety Disorder	χ^2 (1, N=22) = 1.03, p>0.31
Pervasive Development Disorder	χ^2 (1, N=18) = 1.17, p>0.28
MINI diagnoses (Child/Adolescent report)	
Major Depressive Episode	χ^2 (1, N=18) = 2.82, p>0.09
Suicidality	χ^2 (1, N=9) = .74, p>0.39
Dysthymia	χ^2 (1, N=18) = 1.43, p>0.23
Hypo-Manic Episode	χ^2 (2, N=18) = 3.97, p>0.14
Anxiety	C2 only
Panic Disorder	χ^2 (1, N=18) = 3.54, p>0.06
Agoraphobia	χ^2 (1, N=18) = .12, p>0.73
Separation Anxiety Disorder	None
Social Phobia	χ^2 (1, N=18) = .12, p>0.73
Specific Phobia	χ^2 (1, N=18) = 1.66, p>0.20
Obsessive Compulsive Disorder	χ^2 (1, N=18) = .67, p>0.41
Posttraumatic Stress Disorder	None
Alcohol Dependence Abuse	None
Substance Dependence Abuse	None
Tic Disorders	χ^2 (1, N=18) = .67, p>0.41
ADHD	C2 only
ADHD – Inattentive	C2 only

ADHD – Hyperactive	C2 only
ADHD – Total	C2 only
Conduct Disorder / Oppositional Defiant Disorder	C2 only
Conduct Disorder	C2 only
Oppositional Defiant Disorder	C2 only
Anorexia Nervosa	None
Bulimia Nervosa	None
Generalized Anxiety Disorder	None
Pervasive Development Disorder	$\chi^2(1, N=16) = 1.37, p>0.24$

Note: Some MINI data were only collected for Cohort 2 and therefore could not be compared to Cohort 1. This represented by "C2 only." Some MINI diagnoses were not present in either cohort. This is represented by "None."

Table 3. Waitlist Controls compared to MMA participants: Two-way contingency tables and independent samples *t*-tests on demographic variables and study measures.

Demographics	**Control vs. Treatment**
Age	$t(22)= -1.37$, $p>0.19$
BMI	$t(22)= -2.03$, $p>0.06$
Ethnicity	χ^2 (2, N=23) = 2.27, $p>0.32$
Income	χ^2 (6, N=24) = 6.32, $p>0.40$
Medication	χ^2 (1, N=23) = .08, $p>0.78$
Handedness	χ^2 (1, N=22) = .22, $p>0.64$
Therapy	χ^2 (2, N=24) = 1.16, $p>0.56$
Fitness	χ^2 (2, N=24) = 4.37, $p>0.11$
Autonomic @ Time 1	
HP	$t(22)= .73$, $p>0.47$
RSA	$t(22)= 1.17$, $p>0.26$
MINI diagnoses (Parent report)	
Major Depressive Episode	χ^2 (1, N=22) = .77, $p>0.38$
Suicidality	χ^2 (1, N=22) = 4.07, $p>0.13$
Dysthymia	None
Hypo-Manic Episode	χ^2 (1, N=22) = .23, $p>0.63$
Anxiety	C2 only
Panic Disorder	χ^2 (1, N=22) = .23, $p>0.63$
Agoraphobia	χ^2 (1, N=22) = .23, $p>0.63$
Separation Anxiety Disorder	None
Social Phobia	χ^2 (1, N=22) = .11, $p>0.75$
Specific Phobia	χ^2 (1, N=22) = 1.50, $p>0.22$
Obsessive Compulsive Disorder	χ^2 (1, N=22) = .23, $p>0.63$
Posttraumatic Stress Disorder	None
Alcohol Dependence Abuse	None
Substance Dependence Abuse	None

Tic Disorders	χ^2 (1, N=22) = .23, p>0.63
ADHD	C2 only
ADHD - Inattentive	χ^2 (1, N=22) = 1.09, p>0.30
ADHD – Hyperactive	χ^2 (1, N=22) = .01, p>0.91
ADHD – Total	χ^2 (1, N=22) = 1.09, p>0.30
Anorexia Nervosa	χ^2 (1, N=22) = .23, p>0.63
Bulimia Nervosa	None
Generalized Anxiety Disorder	χ^2 (1, N=22) = .49, p>0.48
Pervasive Development Disorder	χ^2 (1, N=18) = .72, p>0.40
MINI diagnoses (Child/Adolescent report)	
Major Depressive Episode	χ^2 (1, N=18) = .64, p>0.42
Suicidality	χ^2 (1, N=18) = 2.25, p>0.33
Dysthymia	None
Hypo-Manic Episode	χ^2 (1, N=22) = .23, p>0.63
Anxiety	C2 only
Panic Disorder	χ^2 (1, N=22) = .23, p>0.63
Agoraphobia	χ^2 (1, N=22) = .23, p>0.63
Separation Anxiety Disorder	None
Social Phobia	χ^2 (1, N=22) = .11, p>0.75
Specific Phobia	χ^2 (1, N=22) = 1.50, p>0.22
Obsessive Compulsive Disorder	χ^2 (1, N=22) = .23, p>0.63
Posttraumatic Stress Disorder	None
Alcohol Dependence Abuse	None
Substance Dependence Abuse	None
Tic Disorders	χ^2 (1, N=22) = .23, p>0.63
ADHD	C2 only
ADHD – Inattentive	χ^2 (1, N=22) = 1.09, p>0.30
ADHD – Hyperactive	χ^2 (1, N=22) = .01, p>0.91

ADHD – Total	χ^2 (1, N=22) = 1.09, p>0.30
Conduct Disorder / Oppositional Defiant Disorder	C2 only
Conduct Disorder	C2 only
Oppositional Defiant Disorder	C2 only
Anorexia Nervosa	χ^2 (1, N=22) = .23, p>0.63
Bulimia Nervosa	None
Generalized Anxiety Disorder	χ^2 (1, N=22) = .50, p>0.48
Pervasive Development Disorder	χ^2 (1, N=16) = .15, p>0.70

Note: Some MINI data were only collected for Cohort 2. Because of this incomplete data, chi squares were not computed here comparing WL to MMA. This represented by "C2 only." Some MINI diagnoses were not present in either group. This is represented by "None."

Table 4. Group mean (SD), stability coefficients, and effect sizes for HP and RSA during resting baseline conditions assessed at two Visits – pre- and post-intervention.

Measure	Visit 1 mean (SD)	Visit 2 mean (SD)	Pearson Correlation (*r*)	V1 to V2 *t*-value	V1 to V2 Cohen's *d*
WL (*n*=5)					
HP (ms)	773.89 (142.21)	702.20 (75.85)	.39	1.21	0.50
RSA (ln ms^2)	7.09 (1.19)	6.92 (1.38)	.97**	1.12	0.15
MMA (*n*=15)					
HP (ms)	730.94 (110.49)	791.19 (115.69)	.56*	-1.34	0.39
RSA (ln ms^2)	6.39 (1.22)	6.62 (1.65)	.87**	-1.01	0.16

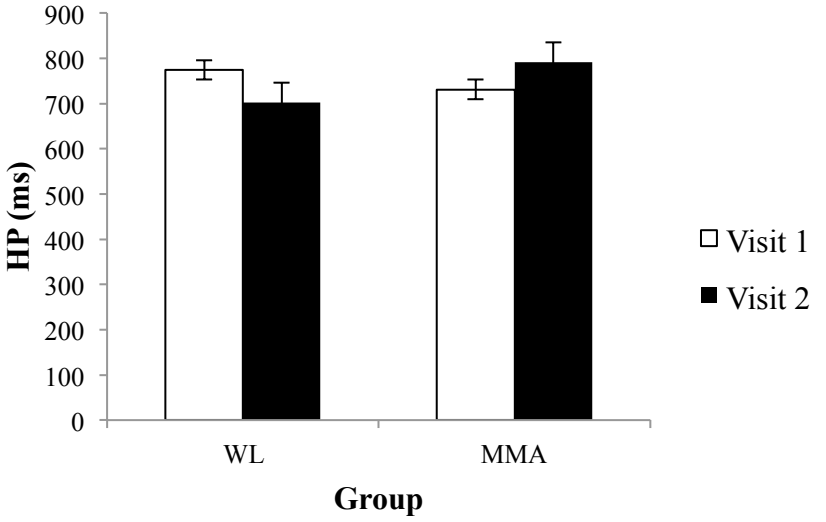
- Group *n*'s represent pairs with data at both Visits
- Significance related to stability across time (by Pearson Correlation) is indicated by * = $p < 0.05$, ** = $p < 0.005$
- Measures of Cohen's *d* are computed using the variance from Visit 1

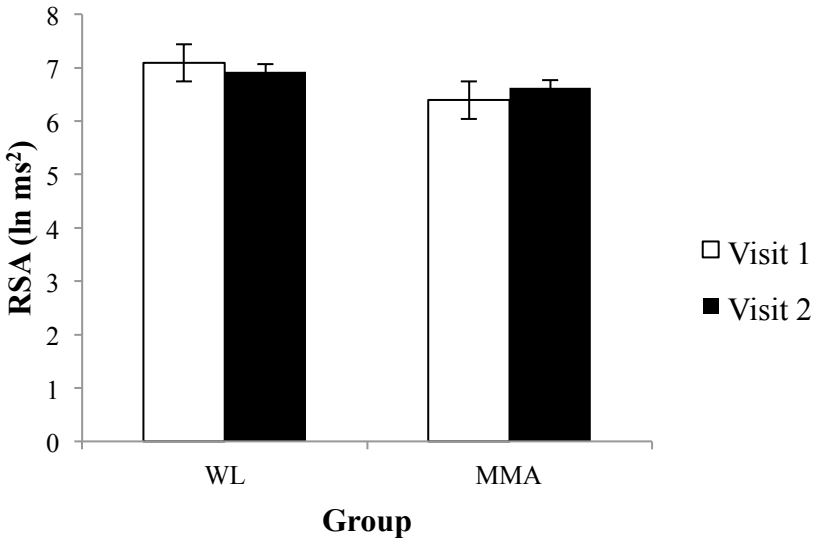
Table 5. Group means (SD) for HP and RSA during resting baseline conditions at Visit 1 for the ADHD subgroups, in all participants.

Measure	HP (ms)	RSA (ln ms^2)
	Visit 1 Mean	Visit 1 Mean
ADHD subgroup	(SD)	(SD)
No diagnosis	717.51	6.47
(*n*=6)	(88.38)	(0.34)
Inattentive	783.26	7.32
(*n*=7)	(125.54)	(1.12)
Hyperactive/Impulsive	677.61	6.61
(*n*=2)	(27.67)	(0.07)
Combined	734.92	5.94
(*n*=9)	(136.65)	(1.53)

Note: No Diagnosis subgroup consists of participants who did not exceed any of the Conners subscales. Combined subgroup consists of participants who exceeded the clinical cutoff *T*-scores for both subscales (inattentive and H/I). When these participants exceeded both clinical cutoff *T*-scores, they were eliminated from the individual subgroup.

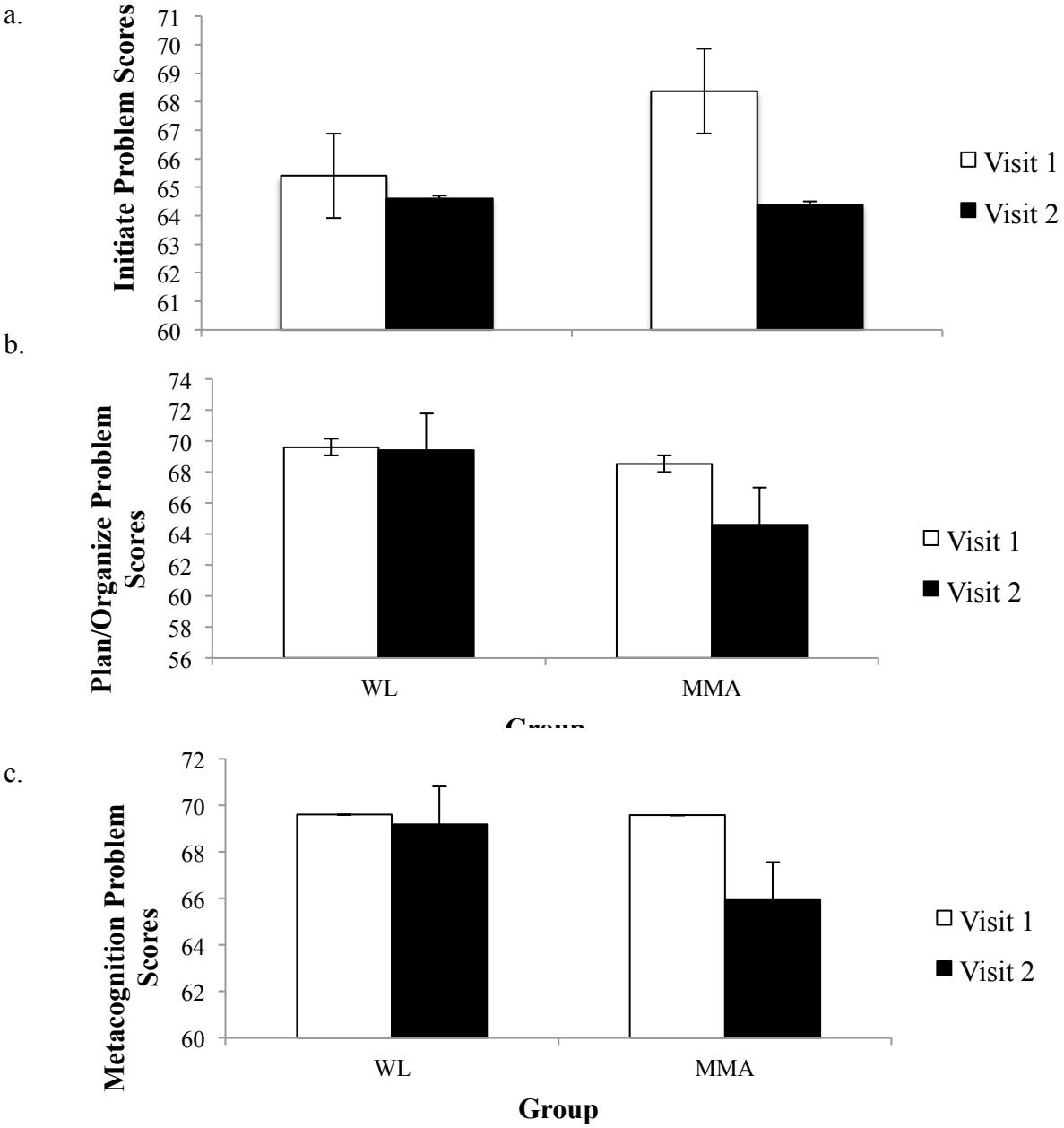
Figure 1. Group differences and change over time in mean levels of resting heart period (HP) and respiratory sinus arrhythmia (RSA).





Note: Bars represent standard error

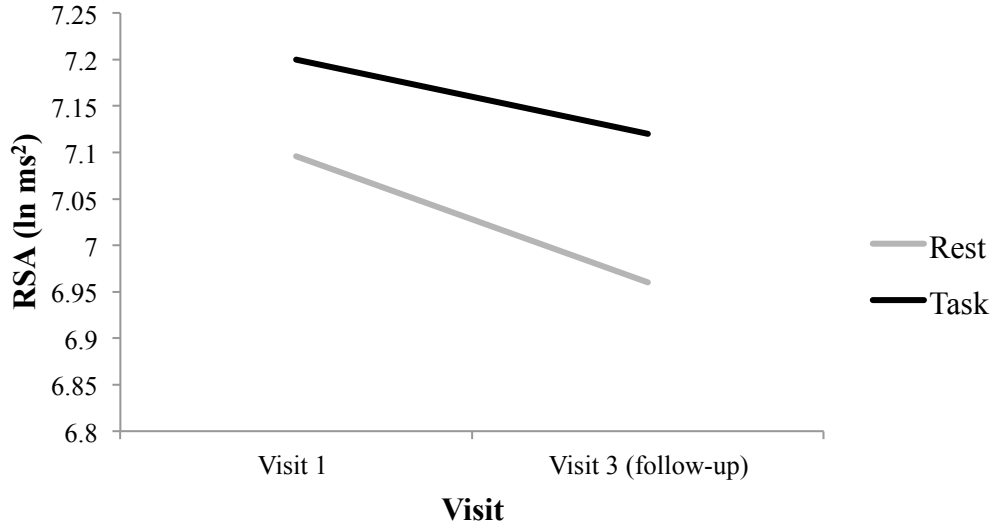
Figure 2. Change in mean levels of parent-reported BRIEF in response to MMA.



Note: Bars represent standard error

Figure 3. Change in respiratory sinus arrhythmia (RSA) from resting to task, by Group

a. WL



b. MMA

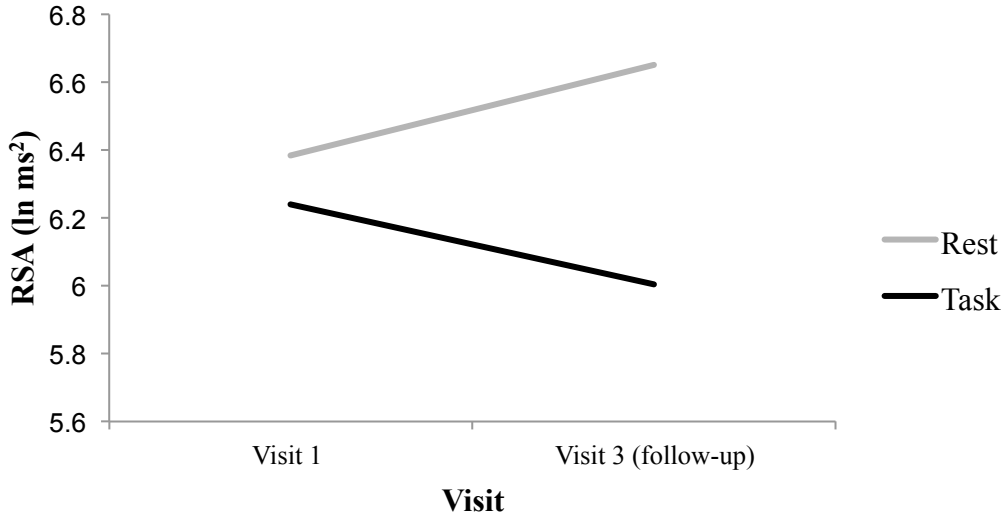
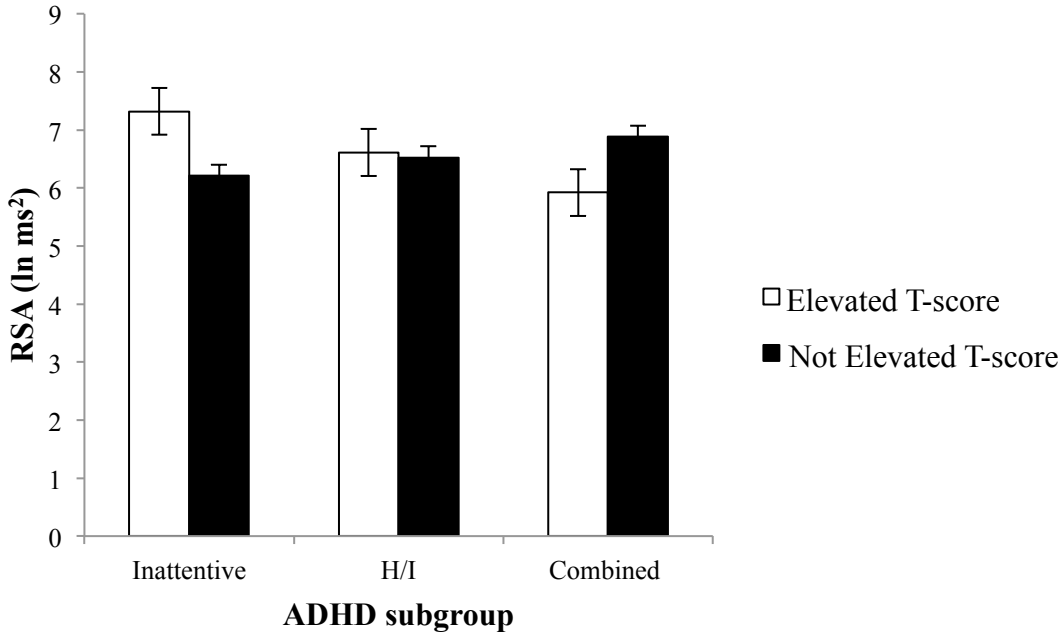


Figure 4. Differences in respiratory sinus arrhythmia (RSA) within ADHD subgroups at Visit 1.



Note: Bars represent standard error

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