Examining the Impact of Motivation on Working Memory Training in Youth With ADHD

by

Mahsa Sadeghi Janbahan

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Author's Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required revisions, as accepted by my examiners.

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Abstract

Background: Working memory (WM), the ability to temporarily store and manipulate information, has been noted as a deficit in children with attention deficit hyperactivity disorder (ADHD) and may be causally related to other cognitive impairments in this clinical population. Cogmed, a computerized WM training program, appears to yield WM improvements although claims of transfer to other domains such as academic achievement are not widely supported by research. Individual differences such as motivation have been suggested as mediating factors, though motivation has not been directly assessed in studies of Cogmed to date.

Objective: The overall objective was to examine motivational influences on ADHD youths' experience with Cogmed using complementary quantitative and qualitative approaches. Aim 1 examined whether individual differences in motivational styles were correlated with a metric of training engagement and scores on transfer outcomes. Aim 2 explored youth's self-reported motivation and subjective experience from a post-intervention interview.

Methods: Data were collected as part of a larger study contrasting a modified Cogmed protocol (n = 20) with physician-monitored standard of care (n = 20) in a community sample of rigorously diagnosed ADHD youth 8 – 14 years of age. Youth in both groups completed comprehensive assessments at baseline, post-intervention (post 1), and again 3 months afterward (post 2). The current study focuses on 10 ADHD youth randomized to the modified Cogmed group who also completed an adapted Self-Regulation Questionnaire (SRQ) and participated in a semi-structured motivational interview at the post 2 follow-up.

Results: The subset of ADHD youth who were the focus of this study (n = 10) did not differ on demographic, clinical characteristics, or baseline measures when compared with ADHD youth who were randomized to the modified Cogmed group prior to inclusion of the SRQ and

motivational questionnaire (n = 10). In our subset of ADHD youth, all showed perfect adherence to the modified Cogmed protocol. Youth who were more externally motivated started modified Cogmed training at a higher level of performance and also reached higher peak performance during the intervention program. At follow-up, higher levels of external motivation also predicted better spatial working memory and lower self-concept, whereas higher levels of introjected/identified motivation predicted worse academic performance. Qualitative analyses suggested that youth displayed flexible motivation with regard to their participation in modified Cogmed training and perceived subjective improvements in their everyday life function.
Conclusions: ADHD youth endorsed multiple types of motivation when motivation was assessed using quantitative and qualitative approaches and reported that modified Cogmed training was useful. Higher external motivation demonstrated a more robust association with modified Cogmed training engagement and better scores on select outcome measures compared with other motivational styles.
Keywords: ADHD, intervention, Cogmed, motivation

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Literature Review and Introduction

Attention-deficit/hyperactivity disorder

Attention-deficit/hyperactivity disorder (ADHD) is a prevalent childhood-onset neurodevelopmental disorder. Current diagnostic criteria for ADHD, outlined in the *Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition* (DSM-5; APA, 2013), include impairing symptoms of inattention and/or hyperactivity-impulsivity that manifest prior to age 12 years, persist for at least six months, and are present in two or more settings. Symptoms of inattention may include difficulty sustaining attention, not listening, forgetfulness, disorganization, difficulty planning, not keeping track of schedules and materials, and making careless mistakes that appear 'sloppy.' Hyperactivity/impulsive may be represented by difficulty sitting still, being fidgety or restlessness, talking excessively, interrupting others, and having trouble waiting for one's turn. Taken together, the diagnostic criteria outlined in DSM-5 reflect a pattern of enduring, developmentally inappropriate behaviours, not better explained by another disorder.

ADHD occurs in approximately five to eight percent of children worldwide, with current estimates suggesting five percent prevalence in Canada (Faraone et al., 2003; Polanczyk et al., 2007). At least 10 percent of children seen in pediatric settings present with ADHD-related symptomology, and up to half of children in psychiatric populations have ADHD (Biederman, Newcorn, Sprich, 1991). Males are diagnosed with ADHD at least twice as frequently as females (APA, 2013), potentially because females are less likely to present with hyperactivity and correlated disruptive or oppositional behaviours (Spencer, Biederman, Mick, 2007; Szatmari, 1991). The two symptoms dimensions of ADHD were derived factor analytically and are represented by three subtypes of the disorder: predominantly inattentive (20 to 30 percent), predominately hyperactive/impulsive (up to 15 percent), and combined presentation (50 to 75 percent (Lahey et al., 1994; Spencer, Biederman, Mick, 2007). With development, there is a natural waning of hyperactivity-impulsivity whilst inattention tends to persist or worsen (Faraone, Beiderman, & Mick, 2005). Nevertheless, as many as 60 percent of youth who are diagnosed with ADHD will have impairing symptoms that persist into adulthood even if they no longer meet full diagnostic criteria for the disorder (Faraone, Beiderman, & Mick, 2005). In addition, all ADHD subtypes experience adaptive impairments, above and beyond comorbidities (Barkley, 2015; Miller & Hinshaw, 2012). In childhood and adolescence, ADHD is strongly associated with increased risk for accidental injury, decreased academic achievement, impaired family and peer interactions, emotion dysregulation, and long-term risk for substance abuse (Goldman et al., 1998; Miller & Hinshaw, 2012). These problems tend to persist into the adult years, as reflected by decreased occupational performance, higher risk of unemployment, as well as elevated marital and interpersonal difficulties in adults who were diagnosed with ADHD as children (Murphy & Barkley, 1996; Biederman et al., 1993). Taken together, these findings indicate that ADHD is a common neurodevelopmental disorder in which chronicity of symptoms and impairments is a central feature.

Estimates of heritability for ADHD are 0.7 to 0.8, implicating genetic and/or gene-environment interactions in the etiology of the disorder (Tannock, 1998; Nigg, 2006). Several other biological risk factors have been identified, including prenatal exposure to substances, environmental toxins such as lead contamination, and low birth weight (Spencer, Biederman, & Mick, 2007). Rutter et al. (1975) also found that an aggregate of psychosocial adversity, including marital conflict, lower socioeconomic status, and parental mental disorder, led to an increased risk for developmental psychopathology including ADHD, further highlighting the impact of environmental variables on the ontogenesis of the disorder. Further exacerbation of ADHD symptomatology has been shown in ADHD families where negative or controlling parenting disciplines were used (Biederman et al., 1995). It thus appears that both genetic and environmental factors are important insofar as understanding the causes of ADHD and modifiers of its course. As discussed further below, executive functions are cognitive control process that have more recently been identified as being relevant to our understanding of ADHD.

Executive Functions

Executive functions (EF) are highly heritable cognitive control processes that facilitate self-initiated, goal-oriented behaviour (Teuber, 1972; Friedman et al., 2008; Lezak, 2004; Miyake et al., 2000). EF-related processing allows for actions such as goal management, decision making, planning, and organizing of actions and cognitions (Friedman & Miyake, 2017; Welsh & Pennington, 1988). EFs are important in the development and attainment of abilities such as academic achievement, particularly math and reading (Borella et al., 2010; Gathercole et al., 2004; Diamond, 2013), learning and memory (Bjorklund & Douglas, 1997), social-emotional regulation, and quality of life (Diamond, 2013; Vaughan & Giovanello, 2010).

Historically, EFs were studied in the context of individuals with frontal lobe damage. These individuals classically presented with dysregulated behaviour and impairments on complex neuropsychological tasks with known sensitivity to frontal lobe dysfunction – leading many to be referred to as “frontal tasks” rather than tasks of EF per se (e.g., Banich, 2009; Jurado & Roselli, 2007; Stuss, 2011). More contemporary work has demonstrated, however, that these EF tasks are sensitive to disruption of broad neuroanatomical networks in addition to traditionally “executive” frontal areas of the brain, including subcortical regions such as the basal ganglia and dopaminergic reward-learning pathways (Bettcher et al., 2016; Hazy, O’Reilly, &

Frank, 2006; O'Reilly & Frank, 2006; see Cortese et al., 2011 and Castellanos & Proal, 2012 for neural correlates of EF in ADHD specifically).

Though initially viewed as a unitary construct, Teuber (1972) theorized that EFs are diverse processes that share a common driving element. Miyake et al.'s (2000) unity and diversity framework was particularly influential in challenging the unitary perspective of EF, instead conceptualizing EF as a set of separable, yet inter-related skills that are differentially related to other task performance and real-world behaviours (see also Alvarez & Emory, 2006). Skills that are viewed as foundational to this EF construct include response inhibition, cognitive flexibility, and working memory updating. Response inhibition is the intentional and deliberate ability to inhibit automatic or pre-potent responses and is supported by the right inferior frontal cortex (e.g., Nigg, 2000; Aron, Robbins, & Poldrack 2004; see also Aron & Poldrack, 2005). Cognitive flexibility, on the other hand, is required to switch between different mental sets and is supported by the anterior cingulate (Allport & Wylie, 2000; Corbetta & Shulman, 2002; Monsell, 1996; Normal & Shallice, 1986; Posner & Raichle, 1994; Szczepanski et al., 2013). A model of working memory, perhaps best described and validated by the work of Baddeley (1992), consists of two systems that separately maintain verbal and visual-spatial information and a central executive that controls the regulation of cognitive processes linked to the frontal lobe (i.e., EFs). Updating the contents of working memory has been associated with prefrontal regions such as the dorsolateral prefrontal cortex (Jonides & Smith, 1997; Stuss, Eskes, & Foster, 1994) as well as frontostriatal and frontoparietal pathways (O'Reilly & Frank, 2006; Darki & Klingberg, 2015). In a more recent revision of Miyake's model (Miyake & Friedman, 2012), a common EF is posited to reflect the active maintenance of goal-relevant information with 'nested' skills reflecting updating and shifting. Regardless of how EF is conceptualized, however, the relevance of the aforementioned executive skills to "goal formation, planning, carrying out goal-directed plans, and effective performance" is widely supported in the literature (Jurado & Roselli, 2007; Lezak, 2004).

Executive Functions and ADHD

EF deficits are moderately associated with all ADHD subtypes and have been linked to poorer outcomes within this clinical population (Biederman et al., 2004; Moffitt et al., 2011; Nigg et al., 2002; Stuss & Alexander, 2000; Woods, Lovejoy, Ball, 2002). Although ADHD is now recognized as a heterogeneous disorder in which less than half of diagnosed children show impairment on any EF task (e.g., Nigg et al., 2005), early neuropsychological models attempted to elucidate a single core EF deficit that was causally implicated in the disorder. One leading candidate was response inhibition, based on observations that children with ADHD were behaviourally disruptive and had difficulty with delayed gratification (Barkley, 1997; Barkley & Ullman, 1975; Cunningham & Siegel, 1987; Quay, 1997; Schachar, Tannock, & Logan, 1993). Lesion studies with adults further demonstrated that individuals who sustained damage to the frontal lobes sometimes presented with secondary (or acquired) ADHD – especially behavioral impulsivity (Stuss & Benson, 1986). Additional evidence supporting response inhibition as a core neuropsychological deficit in ADHD came from studies using go/no-go, stop-signal, or delayed response tasks, in which children with ADHD tended to perform worse than their typically-developing peers (Barkley, 1997; Homack & Riccio, 2004; Ljiffjit et al., 2005; van Mourik, Oosterlaan, & Sergeant, 2005). Response perseveration, or an inability to update rules, was also noted in studies of ADHD children and was thought to be a secondary deficit resulting from the core problem in inhibition (Fuster, 1989). Indeed, much of the early literature in this area pointed to inhibitory difficulties as a core feature of ADHD that led to more general executive dysfunction, as reflected in impaired neuropsychological task performance (Pennington & Ozonoff, 1996).

In 2005, however, a meta-analytic review of ADHD studies assessing EF encouraged the field to examine a multifaceted model of core deficits (Willcutt et al., 2005). The review suggested that ADHD is associated with several EF weaknesses, including inhibition and also WM, above and beyond the influence of intelligence or co-occurring disorders (see also Snyder et al., 2015). This wider-scope consideration of EF deficits in ADHD led to an interest in other core EFs, particularly in a meta-analysis of studies conducted between 1997 and 2003, in which WM was assessed in children and adolescents with ADHD (Martinussen et al., 2005). This meta-analysis documented moderate to large impairments in WM, with impairments being of larger magnitude in visuo-spatial compared to verbal tasks, though more recent reviews have found large effect sizes in both WM domains (Kasper, Alderson, & Hudec, 2012; Sowerby, Seal & Tripp, 2010). WM deficits have been associated with symptoms of inattention (Burgess et al., 2010), social problems (Kofler et al., 2011), lower academic achievement in math, reading, and listening comprehension, as well as fluid reasoning (Fried et al., 2016; Alloway, Gathercole, & Elliot, 2010; Swanson & Kim, 2007). Stimulant medications, the first-choice treatment for ADHD, do not seem to address EF deficits such as WM impairments (Biederman et al., 2008) and benefits of stimulants do not extend to academic or social contexts (Abikoff et al., 2004), particularly in the long-term (Molina et al., 2009).

Given the common and highly persistent nature of ADHD, interventions that prevent the emergence of this disorder, promote its remission, and mitigate associated impairments are an important goal for research. There remains much work to be done in this regard, owing to a lack of specificity regarding the factors that cause ADHD and modify its course.

Computerized WM Training

Efforts to target clinically meaningful change for individuals with ADHD have led to the development and now wide-spread use of computerized WM training interventions. Cogmed RM (Klingberg, Forssberg, & Westerberg, 2002, www.cogmed.com), an intensive WM intervention for youth, is designed to train both visuospatial and auditory WM through repetitive trials on game-like tasks (see Appendix A). Youth are required to both maintain and manipulate stimuli in various adaptive tasks, such as remembering strings of digits, or sequences of shapes with each trial on a given task adjusting difficulty based on performance, such that correct trials are followed by heightened demands while incorrect trials have diminished demand in subsequent trials. To maximize engagement, Cogmed facilitates the use of feedback and rewards during tasks, such as side-bars showing performance or a robot racing game reward. Certified Cogmed coaches are also used to track performance and provide encouragement or trouble-shooting advice. This intense, adaptive protocol is purported to enhance neuroplasticity and result in positive clinical change, with one study by McNab et al. (2009) suggesting dopaminergic D1 receptors in fronto-parietal regions as likely targets of the intervention.

Numerous studies have shown that the training of WM through Cogmed leads to improvements on the tasks themselves for various populations, including youth with ADHD (e.g., Beck et al., 2010; Dahlin, 2011; Green et al., 2012; Klingberg et al., 2005; Mezzacappa & Buckner, 2010). Improvements on trained tasks (i.e., Cogmed itself) are often cited as WM improvements, with studies showing a moderate magnitude of improvements (d = 0.63; Rapport et al., 2013). In the first randomized-controlled trial study of Cogmed in youth with ADHD, improvements in non-trained tasks (e.g., spatial span, Stroop, Raven's matrices) and parent ratings of inattention were demonstrated post-intervention (Klingberg et al., 2005).

These improvements are often cited as transfer effects, where gains on non-trained tasks (i.e., anything other than Cogmed) are thought to show a transfer of WM improvement to other domains. Tasks can be categorized as *near-transfer* when similar to trained WM tasks, such that stimuli and processing requirements remain the same. For example, improvements on a non-trained visuospatial WM task, such as a Spatial span task, after training on the Cogmed visuospatial WM task, would reflect a near-transfer effect. Tasks may be categorized as *far-transfer* when there is no direct contextual similarity to the trained WM task, or when the task is considered more "downstream." For example, improvements in parent ratings of inattention after Cogmed would reflect a *far-transfer* effect.

Rapport et al. (2013)'s review of WM training in ADHD suggests that most randomized-controlled studies of Cogmed show WM improvements on near-transfer tasks, though effect sizes are small (d = 0.23). Simons et al. (2016) argue that near-transfer improvements reflect training gains, as improvements are seen when tasks overlap with trained tasks and not when tasks have distinct properties. For example, the most commonly reported near-transfer improvement is on the Digit Span task (Akerlund et al., 2013; Bjorkdahl et al., 2013; Borella et al., 2010; Brehmer et al., 2012), a WM measure almost identical to a task on Cogmed.

Improved WM after training is claimed to generalize not only to non-trained near-transfer tasks, but also far-transfer abilities such as math and reading (Soderqvist & Bergman Nutley, 2015), cognitive functioning (Bjorkdahl et al., 2013; Akerlund et al., 2013; Borella et al., 2010; van der Molen et al., 2010) and ADHD symptom reductions (Gropper et al., 2014; Beck et al., 2010; Klingberg et al., 2005). Notably, these far-transfer effects are not consistently demonstrated (Green et al., 2012; Gray et al., 2012; Chacko et al., 2014; van Dogen-Boomsma et al., 2014). Indeed, it has been suggested that far-transfer improvements are negligible or nonsignificant (Rapport et al., 2013; Melby-Lerbag & Hulme, 2013). To date, only one systematic review of transfer effects has noted far-transfer effects from WM training, particularly in fluid intelligence, but only in studies reporting improvements in attention (Greenwood & Parasumaran, 2015). Given methodological variability in studies of transfer, it is unlikely WM training consistently improves fluid intelligence in this manner. A more recent review suggests that Cogmed studies have failed to find long-lasting gains on EF tasks of sustained attention or nonverbal reasoning, academic abilities such as word reading, sentence comprehension, spelling, or math, and no evidence of reductions in inattention when methodological errors are accounted for (Simons et al., 2016). Previous studies of WM interventions have suggested individual differences in attitudes and motivation for training may influence transfer outcomes (Jaeggi et al., 2014; Karbach et al., 2014; Bjorkdahl et al., 2013; Guesgens et al., 2007; van der Donk et al., 2016), though this has not been directly assessed in studies of ADHD to date.

Motivational Styles

Self-determination theory (SDT) focuses on the kind of motivation (i.e., the regulatory style) displayed in a behaviour (Ryan & Deci, 2000). This theory does not simply ascribe an *amount* of motivation exhibited, but seeks to label the kind of motivation that results from varying levels of the three psychological needs. SDT posits that the psychological needs of competence (perceived mastery), relatedness (social connection), and autonomy (freedom to follow interests) are important in understanding goal pursuit. The fulfillment of competence and autonomy are necessary for intrinsic motivation, and relatedness has been shown to influence maintenance of intrinsic goal pursuit (Deci & Ryan, 2012). Behaviours that are intrinsically motivated are carried out because they are interesting, and would be completed in the absence of reward/consequence (Ryan & Deci, 2000).

In contrast, extrinsically motivated behaviours are controlled by specific external contingencies, and not linked with the three SDT psychological needs (Ryan & Deci, 2000; Deci, Koestner, & Ryan, 1999). Extrinsic motivation is traditionally viewed as a negative approach to tasks, as external rewards or incentives are often associated with observed decreases in time and effort on a task (see Deci et al., 1999 for review). There are four types of extrinsic motivation, based on how internalized external regulations become. SDT refers to internalization as the process of integrating and revising formerly external regulations into the self-representation, making an individual *self-determined* in their actions (Ryan & Deci, 2000). The most self-determined type of extrinsic motivation, integrated regulation, requires individuals to integrate their ideas about the importance of a behaviour with other aspects of the self (Pelletier, Tuson, & Haddad, 1997; Ryan & Deci, 2000). For example, a WM intervention participant with integrated regulation may complete the program because they believe it could be good for their well-being, something they find important to their self-identity. The next regulation style, identified regulation, involves recognition and acceptance of the value of a behaviour, though remains extrinsic given that the prescribed value is an instrumental gain (Ryan & Deci, 2000). A WM intervention participant who completes the training to improve their memory is expressing identified regulation. Introjected regulation, where external contingencies are maintained by the individual themselves, involves partial internalization of external regulation without integrating any values of the self (2000). Participating in the WM intervention because a parent asked them to do so would be an introjected state. Comparing this to pure extrinsic motivation, where a participant may complete the intervention for some prize, demonstrates the varying levels of internalization that occur. The four regulatory styles fall along a continuum with completely controlled, nonself-determined regulation and entirely autonomous, self-determined regulation at either end.

Ryan & Connell (1989) describe that behaviours often expected of children, including academic activities or interventions, are not interesting in the way necessary for intrinsic motivation. Further, fully internalizing a behaviour is unlikely in youth (Ryan & Connell, 1989), thus measures of regulatory styles intended for youth present integrated regulation in place of intrinsic.

Much of the literature on motivation suggests that intrinsic motivation is more beneficial than extrinsic, and is linked to persistence in performance, psychological well-being, and likelihood to approach tasks rather than to procrastinate (Deci & Ryan, 2012; Thoman, Smith, & Silvia, 2011; Senecal, Koestner, & Vallerand, 1995). Burton et al. (2006) found that students with more self-determined motivation were less impacted by poor academic performance compared to those expressing identified motivation. As well, Thoman et al. (2011) found that participants were more likely to show persistence in completing an interesting task than one designed to elicit positive affect.

Extrinsic motivation is traditionally viewed as a negative approach to tasks, as external rewards or incentives are often associated with observed decreases in time and effort on a task

Despite the traditional view that intrinsic motivation is more beneficial than extrinsic, it appears that one is not necessarily more beneficial than the other. Specifically, intrinsically motivated behaviours are also related to poorer quantifiable performance on a task, and less overall productivity compared to extrinsic behaviours (Cerasoli, Nicklin, & Ford, 2014; Sansone, Smith, Thoman, & Macnamara, 2012). Extrinsic motivation has been found to predict academic performance more strongly than intrinsic (Sansone et al., 2012; Burton et al., 2006), particularly with regard to objective outcomes such as grades on a test (Cerasoli, Nicklin, & Ford, 2014).

However, intrinsic motivation was found to predict the quality of performance, such as depth of knowledge (Cerasoli, Nicklin, & Ford, 2014). Extrinsic motivation and external incentives appear to be most beneficial for individuals who procrastinate (Tice & Baumeister, 1997; Cerasoli, Nicklin, & Ford, 2014), and in tasks of sustained attention (Halkjelsvik & Rise, 2015).

Recent research provides evidence that motivational styles are not fixed, and that individuals choose strategies based on the task at hand (Scholer & Miele, 2016; Wolters, 2011; Wolters, Benzon, & Arroyo-Giner, 2011). This suggests that individuals may exhibit different regulatory styles based on different environmental conditions, and can express more than one type of style. Given that both intrinsic and extrinsic motivational styles have their distinct advantages (and disadvantages), it is important to study both the type of motivation and the change in motivation expressed by youth. Currently, there is a paucity of studies addressing any of these factors in youth with ADHD.

Current State of Motivation Studies in ADHD

Motivational influences on WM intervention outcomes have not been studied to date in youth with ADHD, though achievement motivation in academics and neuropsychological test scores has been addressed. Achievement motivation results from a combination of the desire to succeed and desire to avoid failure at a given task or goal (McClelland et al., 1953), and drives individuals to meet the demands of a task (Covington, 2000). Ultimately, the desire to succeed at a task leads to effortful engagement with that task. Indeed, achievement motivation, engagement, and inattention were found to share high common variance in their relationship to academic outcomes (Plamondon & Martinussen, 2015). The assessment of motivation based on the desire to achieve does not, however, reveal the level of self-determined motivation.

A study of children with ADHD where achievement motivation was assessed using rating scales of approaching behaviours (e.g., child is eager to learn) and avoiding failure (e.g., child tried to work hard even when tired) found that highly-motivated children with ADHD performed as well as healthy controls on a test of receptive language and mathematical thinking (Gut et al., 2012). The *type* of motivation expressed by these children, however, remains unexplored.

Other studies have considered achievement motivation and engagement with a task through providing incentives or immediate positive feedback, and have found that children with ADHD improve on tasks of response inhibition when given high incentive (Konrad et al., 2000; Carlson & Tamm, 2000; McInerney & Kerns, 2003). Again, this does not provide information about motivational styles, given the use of an external contingency.

Various studies of students with ADHD have shown that overall high levels of motivation (and engagement) are correlated with positive academic outcomes (e.g., Froiland & Worrell, 2016; Martin, 2012c; Froiland, 2011; Carlson et al., 2002). Despite the general finding that increased motivation results in greater improvements, precise definitions of motivation have not been elucidated in the literature thus far. A study by Prins et al. (2011) attempted to address the impact of motivation on computerized WM training, using a WM "game training" program targeting visuospatial WM through an animated story line. Motivation was assessed by amount of time spent on the training, number of game sequences performed, and a subjective questionnaire with questions such as "how much did you like the game?" This study shows similar limitations to those discussing achievement motivation, given that engagement was once again used to extrapolate motivation towards a highly-incentivized intervention. Given the lack of clarity in defining motivation, it is worthwhile to explore *types* of motivational styles in individuals, rather than overall levels of engagement.

This study was part of a larger trial in which 40 ADHD youth (20 per cycle) were randomized to a modified computerized WM training intervention or treatment as usual under the care of their community physician. The purpose of this study was to (a) explore the impact of well-defined motivational styles on built-in Cogmed and post-intervention outcomes, as well as (b) to understand youth's subjective experience and reported motivation from an interview conducted after the intervention.

Methods

This study was jointly approved by the Office of Research Ethics at the University of Waterloo and Tri-Hospital Research Ethics Board for Cambridge Memorial Hospital (CMH) in Waterloo Region. Written informed consent was obtained from all participants after initial phone screening, prior to baseline assessment at CMH. This study is registered as a clinical trial at clinicaltrials.gov, ID number NCT02610244.

Participants and Recruitment

Forty-two youth were recruited through the CMH Outpatient Mental Health Clinic (Figure 1). Youth were between 8 and 16 years of age, resided in Waterloo Region, and were physician-referred due to suspicion of ADHD. After expressing interest in the study, but prior to enrollment, 42 phone screens were conducted by one of the investigators with parents/guardians of youth using the CADDRA ADHD checklist to evaluate current ADHD symptomatology (CADDRA, 2014). All parents/guardians of youth who were phone screened had youth with at least 6 of 9 traits of inattention and/or hyperactivity-impulsivity that were above clinical threshold with regards to severity (i.e., responses indicating that the trait was *pretty much* or *very much* evident). All parents/guardians were invited to CMH with their child or adolescent for formal consent/assent,[1] after which they participated in a psychodiagnostic assessment and baseline psychological testing (described below). One participant withdrew at this point because their family did not believe that it would be feasible for them to make the time commitment required to participate in the study.

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[1]Parents/guardians, along with participating youth, were provided information regarding study purpose and procedure by a registered clinical psychologist prior to engaging in any consultation or assessment. Youth were encouraged to ask questions and were given forms with developmentally appropriate language for either consent (13 years and older) or assent (younger than 13 years).

To be eligible for participation, youth were required to have a primary diagnosis of ADHD per the psychiatric consult. Exclusion criteria were any of the following: (a) no primary diagnosis of ADHD, (b) estimated IQ below 80, (c) reading comprehension below a grade 2 level, (d) significant impairment that would make it difficult to use a computer, and (e) not attending a school within the Waterloo Region or Waterloo Region Catholic District School Boards. One participant was excluded due to low reading.

The ensuing group of 40 eligible youth were then randomized into the modified Cogmed training group (n = 20, M age = 11.56, SD = 2.30, % female = 10) or a group in which they received treatment-as-usual under the care of the referring physician (n = 20, M age = 11.62, SD = 2.08, % female = 35). The study occurred between October 2015 to June 2016 (Cycle 1) and September 2016 to March 2017 (Cycle 2) to ensure that the same teacher provided ratings of participants during their 6-month long involvement in the study. Of note, the treatment-as-usual group is the focus of a separate paper and is not reported further.

Of the 20 ADHD youth who were randomized to modified Cogmed, 19 presented with ADHD-Combined type and 1 met criteria for ADHD-Inattentive type. Fourteen youth (70%) were taking stimulant medication for management of ADHD symptoms. Comorbidities (i.e., secondary diagnoses) in this sample included anxiety disorders (n = 6), oppositional defiant disorder (n = 7), learning disabilities (n = 3), autism spectrum disorder (n = 1), and tic disorder (n = 1). As described further below, mean estimated IQ (M = 106.50, SD = 14.27) and reading comprehension (M = 102.35, SD = 17.83) were in the average range.

Procedure

All testing sessions and WM training were conducted at CMH. Youth underwent psychological testing at three time points: initial visit (baseline), immediate follow-up approximately one week after the 10-week intervention period (post 1), and three-month follow up (post 2). At each of these 90-minute assessments, a clinical psychologist or highly trained research assistant working under the supervision of the clinical psychologist administered well-established and psychometrically validated questionnaires and cognitive tests. Measures were administered in the same fixed order at each assessment as described below. Further, Cycle 2 youth who had participated in modified working memory training completed a self-regulation questionnaire and semi-structured interview regarding their subjective experiences in the intervention program prior to receiving feedback (n = 10). In both cycles, all participants and their parents/guardians attended the final feedback session with a clinical psychologist approximately two weeks following the three-month follow-up. All participants received compensation for transportation or parking, a two dollar Tim Hortons gift card for each session they attended at the hospital, and a $100 iTunes gift card after three-month follow-up. Youth who participated in modified working memory training also were allowed to keep their mini-iPad at the end of the final feedback session. All youth in the control group were provided with the opportunity to receive working memory training following the completion of their involvement in the study.

Working Memory Intervention

Cogmed RM (Klingberg, Forssberg, & Westerberg, 2002, www.cogmed.com), the computerized WM intervention for school-aged children, was modified for use in our study. Our modified version of Cogmed RM required participants to complete three training sessions per week for a 10 week period, rather than five sessions per week for five weeks. All 30 modified sessions were carried out with a clinical psychologist or trained research assistant (i.e. designated coach) in a quiet room with a computer at the hospital, as opposed to the standard at-home administration.

As described elsewhere (Klingberg et al., 2005), Cogmed RM is an adaptive program consisting of 12 visual or auditory WM exercises that adjust task difficulty to the performance of each participant, thereby ensuring that participants are working at their optimal level of challenge. Participants completed 8 of the 12 exercises at each training session. Each session lasted approximately 35 minutes, during which time the coach remained in the room with youth to answer any questions and provide motivational support. Coaches also had access to progress reports provided by Cogmed, tracking trial-by-trial performance and overall weekly performance. These reports were used to provide individualized feedback to youth, in addition to feedback built-in to the computer program as participants completed exercises. Because adherence was 100% in our sample, we used Cogmed-generated outcome measures to assess engagement with the program. To assess average improvement on overall performance, the program calculated an "Improvement Index" by subtracting the Start Index (score on third day of training) from the Max Index (best score throughout training). The Start and Max indices were used, but the difference scores of the Improvement Index will not be reported as they do not reflect engagement.

Cognitive Measures

Wechsler Abbreviated Scale of Intelligence – Second Edition (WASI-II; Wechsler, 2011). Four subtests were administered (Block Design, Vocabulary, Matrix Reasoning, and Similarities) yielding two index scores. Verbal Comprehension Index (VCI) scores, reflecting an individual's ability to understand and use spoken language, were based off of a word-defining task and a task requiring youth to draw similarities between words and concepts. Both subtests were presented orally. The ability to interpret and organize visual information was captured by the Perceptual Reasoning Index (PRI), calculated based on scores from a task involving re-creating images with blocks and a task requiring youth to identify patterns in designs. VCI and PRI standard scores were used to estimate current intellectual functioning at baseline. The internal consistency of the VCI for children aged 6-16, based on the normative sample, is a = 0.93, and a = 0.94 for the PIQ; the full-scale IQ (FSIQ) estimate internal consistency has an average a = 0.93.

Wechsler Individual Achievement Test – Third Edition (WIAT-III; Wechsler, 2009). Four subtests from the WIAT-III were used to assess the academic achievement domains of reading and mathematics. A reading composite score was derived from two subtests: reading fluency, requiring youth to read aloud passages with accuracy, speed, and prosody reflected in scores, and reading comprehension of untimed passages requiring youth to orally respond to questions about the passage. A mathematics composite score was also derived, based on the math problem solving and numerical operations subtests. Math problem solving measured untimed math reasoning skills, in both basic and extended applications, using orally administered questions with visual cues. Numerical operations measured untimed written math calculation skills of integers, geometry, algebra, and calculus, presented in a worksheet format. Internal consistency based on test-retest stability coefficients for the normative sample range from r = .83 to .97 for all subtests, and composite scores reportedly range from r = .90 to .98.

Automated Working Memory Assessment (AWMA; Alloway, 2007). Four subtests of the AWMA were administered on a computer, with all tasks following a span procedure beginning with two-item lists and increasing by one item as youth completed trials correctly; scores were awarded up to the highest span completed correctly. To measure auditory and visuospatial WM, processing scores from two subtests were used; these were selected as they were tasks requiring complex manipulations as opposed to rote memorization. For auditory WM, the listening processing score measured youth's ability to listen to short sentences, decide whether each was true or false, and then report the last word of each sentence in reverse order. Visuospatial WM was measured with the spatial processing score, based on youth's ability to compare two identical shapes, one of which may have been rotated and was presented with a red dot on top, and identify if the shapes were identical or opposite to each other, then remember the location of the red dots in the reverse order they were presented.

Test of Variables of Attention– Combined Visual and Auditory system (TOVA; Greenberg & Kindschi, 1996). The TOVA is a computer-administered continuous performance task and was used to measure components of attention and inhibitory control. Results from this measure were invalidated due to technical issues, and thus will not be reported.

Rating Scales

Beck Youth Inventories – Second Edition (BYI-II; Beck, Beck, & Jolly, 2005), Self Concept Scale. This 20-item self-report questionnaire assesses thoughts of self-competency and self-worth. Items included phrases such as "I feel smart" and "I am just as good as other kids," with responses ranging on a 4-point scale from Never True (0) to Always True (3). The sum of raw scores was used to calculate a *T*-score, with higher scores representing lower levels of distress. The internal consistency of this measure, based on the normative sample of youth ages 7-14, ranges from a = .86 to .91, based on age.

The Child Behaviour Checklist (CBCL) and Teacher Report Form (TRF) from the Achenbach System of Empirically Based Assessment (ASEBA; Achenbach, 2010). The CBCL and TRF were administered to parents and teachers of youth, respectively. Both CBCL and TRF forms consist of 113 items with 3 response choices ranging from Not True (0) – Very True (2), which are factor-analytically coordinated into scales such as anxiety problems, depressive problems, attention deficit/hyperactivity (ADHD) problems, conduct problems, social problems, and somatic complaints. Sums of raw scores for each scale are used to report *T*-scores based on the normative sample. The ADHD problems scale (Cronbach's *a* = .84), based on DSM-oriented symptom presentation, was used from both the CBCL and TRF (e.g., "child is inattentive" or "child can't pay attention for too long").

Behaviour Rating Inventory of Executive Function – Second Edition (BRIEF-2; Gioia et al., 2015). Parent and teacher versions of the BRIEF-2 assess executive functioning skills at home and school, respectively. The 63 items of the BRIEF-2 are scored on a 3-point scale ranging from *Never* (1) to *Often (3)*, with scores tallied into various indices. *T*-scores were calculated based on the raw score sums compared to the normative sample. The internal consistency of these indices, based on the normative sample, is reported to be between *a* = .80 - .98. The Behavioural Regulation Index represents impulse inhibition and self-monitoring, with items such as "acts sillier than others in groups." The Emotion Regulation Index comprises emotional control and problem solving flexibility, such as "has trouble accepting a different way to solve a problem." The Cognitive Regulation Index includes working memory, planning/organizing, and task monitoring, like "does not bring home homework." These indices are totalled into a Global Executive Composite (GEC) score, representing difficulties with the various aspects of executive skills in daily living. GEC scores from both parents and teachers were used.

Assessment of Motivation

The Self-Regulation Questionnaire – Academic (SRQ-A (Ryan & Connell, 1989). The SRQ-A is a 32-item rating scale that assesses behavioural regulation in various situations through multiple-choice format. In our study, the SRQ-A was modified by replacing school-related activities with those pertaining to Cogmed training (e.g., "*It's important to me to try to do well in school*" became "*it was important to me to try to do well in the program*", see Appendix B). Items were presented verbally by a researcher not involved in the WM training, with response options visible to youth. Answers ranged on a four-point scale from "*not true at all*" (1) to "*very true*" (4). Consistent with the SRQ-A, item responses were totalled and mean values were calculated for four scales reflecting varying levels of motivation, including external (item scale reliability *a* = .71), introjected (*a* = .83), identified (*a* = .92), and intrinsic (*a* = .85). The intrinsic motivation scale on the SRQ represents integrated regulation, and is considered to be the most self-determined type of motivation in youth.

Post-Intervention Interviews

A semi-structured interview was administered by a researcher not involved in the WM intervention, in which youth were asked five open-ended questions regarding their reasons for training, subjective changes experienced post-intervention, and perceived supports or reinforcements (see Appendix C). These interviews were audio recorded and transcribed.

Analyses

Descriptive statistics for all 20 ADHD youth (Cycles 1 and 2) who were randomized to the modified Cogmed group are presented in Table 1. No data were missing in our analyses. Standard scores from outcome measures were used in all analyses. Post-intervention changes in outcome measures are reported in a separate paper (see Appendix D for change scores in our subsample). Initially, independent samples *t*-tests were conducted to compare Cycle 1 and 2 demographics and clinical presentation, Cogmed scores, and cognitive outcome measures (keeping in mind that motivational styles could only be assessed in Cycle 2 youth). Next, Pearson correlations of motivational styles using the SRQ and built-in Cogmed scores were calculated. Associations between the SRQ and cognitive outcomes were also explored, using 3-month post-intervention scores, to ensure that the SRQ and outcome measures were assessed at close points in time. All analyses were completed on IBM SPSS Statistics. Finally, QSR International's NVivo 11 was used to qualitatively analyze post-intervention interviews. Keywords from interview transcriptions were coded as emerging themes of motivation towards training.

Results

Cycle 1 and 2 Comparisons

All participants showed adherence to the training program, completing 100% of sessions (30/30 training days). All participants showed improvement on trained Cogmed tasks, as defined by the Improvement Index generated by the program (M = 27.00, SD = 8.10). Baseline scores on the Start Index (M = 75.30, SD = 9.10) and Max Index (M = 102.30, SD = 14.00) were also generated.

Given that primary analyses were only possible with ADHD youth in Cycle 2, ADHD youth in Cycles 1 and 2 were directly compared on demographic and clinical variables, Cogmed indices, and baseline measures to ascertain whether the two groups were similar. Table 1 displays independent samples t-test comparisons for Cycle 1 and Cycle 2 youth (all comparisons df = 18). As shown in Table 1, there were no group differences in ADHD traits or co-morbid symptoms of ODD, Cogmed indices reflecting engagement with the training program, or baseline measures of intellectual functioning, academic achievement, working memory, or related behaviours (all ps > .10).

Motivational Styles and Cogmed Scores

Motivational styles for the 10 Cycle 2 youth randomized to modified Cogmed were derived from the SRQ, administered at approximately 3.5 months post-intervention. Youth were assigned a score corresponding to each of the four motivational styles, with a maximum score of 4 representing high ratings. On average, identified motivation was endorsed most frequently (M = 3.40, SD = 0.54), with responses such as "its important to me" and "I wanted to learn new things" when asked why youth decided to complete training. Youth also endorsed "I enjoyed doing the training" and "the training was fun" as reasons for training on the SRQ, represented by high intrinsic motivation scores (*M* = 3.25, *SD* = 0.57). Introjected motivation was expressed less than identified or intrinsic (*M* = 2.13, *SD* = 0.53), reflecting lower endorsement of responses such as "I wanted my parents/coach to think I'm a good student" or "I would have felt bad about myself if I didn't do the training." External motivation, such as "I'll get in trouble if I don't complete the training" and "It was what I was supposed to do," was least endorsed (*M* = 1.85, *SD* = 0.53). Notably, external and intrinsic motivation were not associated with each other, $r(8) = -.09$, $p = .80$. Motivational styles were not associated with age.

Table 2 shows all associations between Cogmed outcome indices and SRQ motivation styles. There were no significant or trend-level correlations with any of the Cogmed-generated indices (all *p*s > .36). Though non-significant, external motivation appeared to be positively associated with both the Start and Max indices on Cogmed. Numerically, improvement scores were positively associated with identified motivation, and negatively associated with both introjected and intrinsic motivation at similar magnitudes.

Motivational Styles and Cognitive Outcomes

Outcome measures were categorized as near or far transfer depending on task demand and similarity to trained Cogmed tasks. AWMA listening and spatial processing scores were considered near-transfer. All other measures were classified as far-transfer, given that they measured abilities not directly trained in Cogmed. At baseline, no significant associations were found between SRQ motivational styles and tested abilities.

At 3-month follow-up, the near-transfer task of visuospatial WM (AWMA spatial processing) was strongly positively associated with external motivation ($r = .76$). The magnitude of association between intrinsic motivation and spatial processing shows a negative correlation between self-determined motivation and near-transfer visuospatial WM ($r = -.38$). Scores on the far-transfer reading composite were negatively associated with both introjected (r = -.71) and identified motivation (r = -.74). Higher self-concept was strongly negatively correlated with external motivation (r = - .73).

Figures 2 through 8 display scatterplots of outcomes and both intrinsic and extrinsic motivational styles. A few patterns can be noted from these plots. Math composite scores appear to be negatively associated with external motivation, and positively associated with intrinsic motivation. Further, teacher ratings of ADHD problems from the TRF and executive functioning from the BRIEF are negatively correlated with both intrinsic and external motivation. Parent ratings of ADHD problems show a positive link with both motivational styles, though the magnitude of association with intrinsic motivation is greater. Parent ratings of executive functioning and external motivation show a negative link.

Post-Intervention Interviews

Amongst the 10 youth who completed post-training interviews, a summary of themes that emerged through qualitative analyses is presented in Table 4. Most youth who completed training cited improving their memory (n = 7) and focus/attention (n = 8) as reasons for training. Subjective changes post-training most often cited were improved program scores (n = 7), improved focus (n = 6) particularly at school or home, and improved memory (n = 6). Youth endorsed that their internal motivation to complete a training program was a driving factor in their completion of Cogmed (n = 6), as well as the support of parents, teachers, or their Cogmed coach (n = 6), and the iPad they received at the end of training (n = 6). Six youth also endorsed that they found the training to be fun.

Discussion

Results show that a community sample of 20 youth with ADHD successfully engaged with and completed our modified Cogmed RM intervention. In this study, engagement was conceptualized as active completion of the intervention and was assessed via adherence to the training regimen and Cogmed-generated indices reflecting performance. Notably, all of our ADHD youth completed 100% of sessions. Youth completed fewer sessions per week on scheduled after-school times, with costs of transportation covered and coaching made integral to the modified protocol. These particular modifications may have made it more feasible for families to commit to our full program, and speak to the high commitment required of families involved in behaviour-based ADHD interventions. Additionally, all of our ADHD youth demonstrated performance improvements on the Cogmed tasks, as noted by the program-generated Improvement Index. Taken together, these findings indicate that a modified Cogmed protocol that consists of fewer weekly sessions that are distributed over more weeks engenders considerable buy-in from families and produces considerable training gains.

One objective of this study was to determine whether individual differences in motivation accounted for variation in Cogmed training. To do so, we measured four motivational styles using the SRQ (i.e., external, introjected, identified, and intrinsic). The pattern of results from the SRQ suggest that youth expressed flexibility in their motivation, endorsing several types of motivation as reasons for training. The positive association between maximum/start scores on Cogmed and external motivation indicate that it is not simply internal or self-determined motivation that benefit individuals' performance or engagement with a task. Motivation does not appear to be a single, predictable continuum, and it appears that the range of externally-regulated motivational styles could be sufficient for engagement on interventions like Cogmed. Indeed, since high incentive and feedback have been linked to high engagement in previous studies (Konrad et al., 2000; Carlson & Tamm, 2000; McInerney & Kerns, 2003), these built-in features of Cogmed may be enough to elicit engagement and could explain the expression of more external motivation in youth.

Post-intervention interviews support the finding that youth were highly motivated to complete training, with differing types of motivation expressed. Youth cited numerous reasons for training, with the most common motivators being to improve their memory or attention. Youth offered examples of things they wished to improve, such as attentiveness during conversation or instructional learning. Overall, all reasons for training endorsed by youth were internal, goal-driven motivators. Interestingly, then, the open-ended interview elicited far more internal factors compared to the SRQ. It is possible that the forced-choice questions of the SRQ may have led to higher endorsement of external factors, particularly regarding within-program improvements. As well, given that the SRQ focused solely on reasons for training, responses may have differed if given prior to starting the intervention.

Youth who mentioned external rewards such as their iPad gift also reported their own "determination" or "motivation" as supports for training. This aligns with the flexibility in motivational styles expressed on the SRQ, and also suggests that youth showed multi-finality in their motivation, a goal systems theory related to motivation (Kruglanski et al., 2015; Eccles & Wigfield, 2002). Specifically, youth completed a single task (Cogmed) for achievement of several goals, each of which may have been internally or externally regulated (e.g., improving ADHD symptoms *and* receiving a gift). Thus, not only did youth show a flexible motivational approach to the intervention, but also expressed multiple goals. This suggests that exploring types of motivation is crucial to understanding participant experience in ADHD intervention studies, as this nuanced finding would not have been possible if motivation were operationalized as a single construct.

A related objective of this study was to determine whether motivational factors were linked to benefits on near and far transfer outcome measures reflecting cognition and behaviour. SRQ ratings of external motivation were correlated with the near-transfer measure of spatial processing, such that higher endorsement of external motivation was linked to higher spatial processing scores. Given the high level of engagement with Cogmed tasks similar to the spatial processing task used, and the finding that flexible external regulation may suffice for success with such tasks, it is possible that tasks that are similar to trained Cogmed tasks may need less internal motivation. Far-transfer measures of academic achievement show a contrasting link to motivation, namely that higher endorsement of introjected (fairly external) motivation was associated with lower reading and math scores. Tasks that differ substantially from trained tasks could require more interest and self-determination compared to near-transfer tasks. As well, individuals who perform better on tasks may be more internally motivated to do so, as evidenced by the link between low self-concept ratings and high external motivation. However, this trend may depend on the task at hand, as in our sample higher endorsement of intrinsic motivation was linked to higher math scores, but lower reading scores. These trends further suggest that it is imperative to assess motivational styles, as task demands influence expressed regulation style.

Higher endorsement of any motivational style appeared linked with teacher ratings of problems in both ADHD and executive functioning. Parent ratings of ADHD problems, however, suggest that endorsement of motivation is associated with higher problem ratings. A clear pattern did not seem to emerge based on the parent and teacher reports, though a different picture emerged when discussing youth's perceptions of their everyday functioning in post-intervention interviews.

When asked about subjective changes post-intervention, youth reported improvements in Cogmed outcomes consistent with those found quantitatively. Youth also provided examples of improvements in focus, memory, and personal goals such as academic achievement, remembering to do chores, or feeling organized. Though not wholly supported by the cognitive measures, these subjective improvements could be contributors to the increase in youth self-concept, and also reflect global executive improvements noted in parents. Overall, youth endorsed personal success with the intervention.

One limitation to this study is that only Cycle 2 youth were able to complete post-intervention SRQ and interviews, due to the timing of ethics approval. No group differences emerged when comparing Cycle 1 and 2 youth on clinical, Cogmed, and outcome measures, suggesting that both groups were fairly representative of youth with ADHD generally, especially given that our community sample did not exclude co-morbidities or stimulant medication use for management of symptoms. We also note that the study was time and resource intensive and required physician referral, which restricted our sample size and may have attracted youth and families who had an unusually high interest in participating in an intervention study. Further, whilst our modifications to the standard Cogmed protocol intervention were done to ensure feasibility and maximize coaching support, these changes may have made it difficult to measure internal motivation once the study commenced. A major limitation of our design was our inability to quantitatively assess motivation prior to the intervention. Although youth received final feedback on outcome measures after completing the SRQ and exit interview, their coach support during training included continuous feedback on their Cogmed performance.

In conclusion, this study sought to assess the influence of motivational styles on engagement, performance, near and far transfer outcomes with Cogmed. Changes in Cogmed-generated indices demonstrated that training gains are possible for community-sampled youth with ADHD, reflecting successful engagement with the intervention. Further, our results from the SRQ suggest that youth expressed flexibility in their expressed motivational style, based on program engagement and transfer task demands. Post-training interviews suggest that youth felt highly motivated and successful in completing the intervention, with all youth reporting post-intervention improvements at home and school. Future, larger-sample studies measuring motivational styles at baseline can further explore the mediating role of motivation on intervention outcomes.

Figure 1. *Consort flow diagram of participant recruitment and enrollment.*

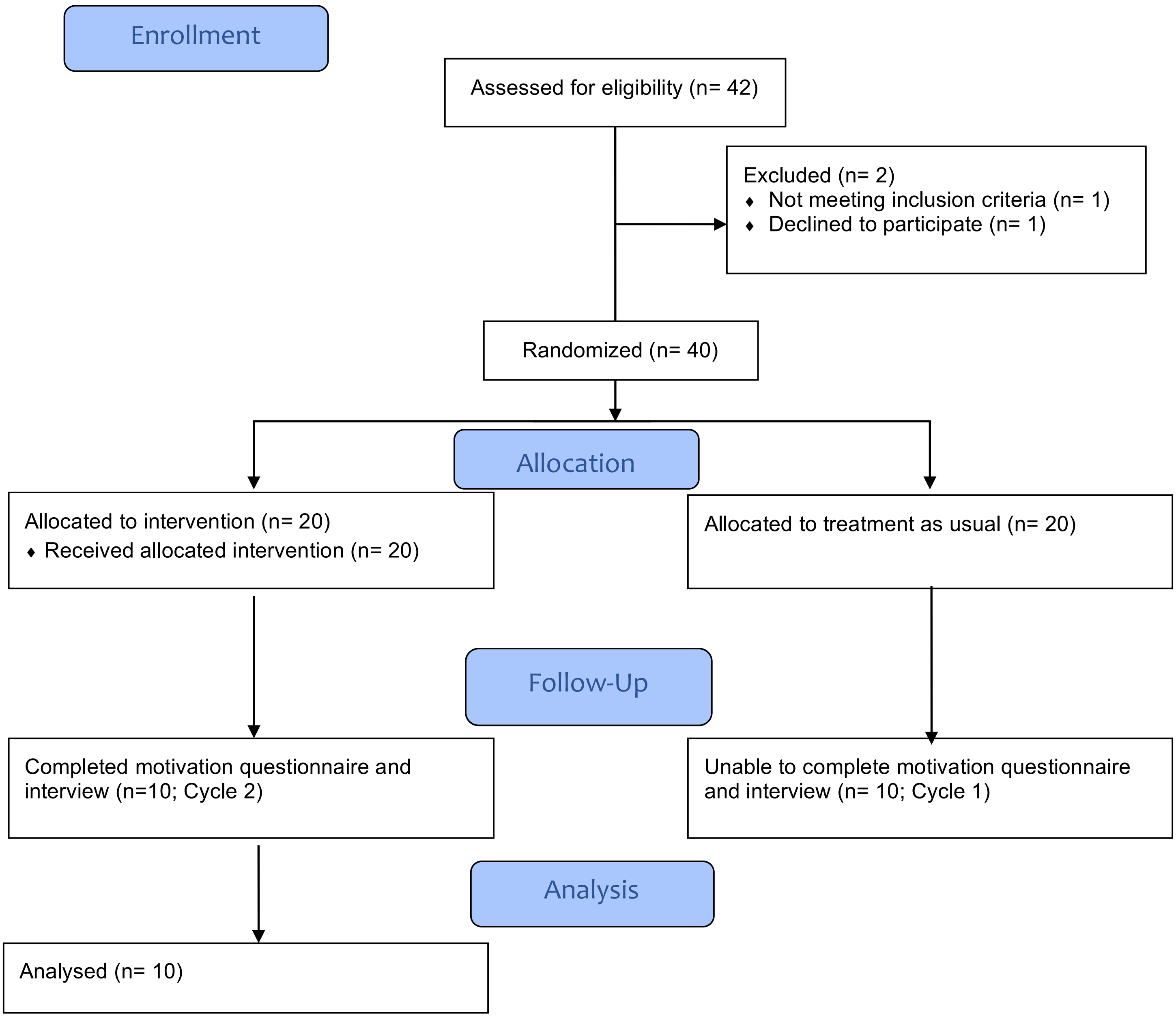


Figure 2. *Scatterplots of intrinsic and external motivation with AWMA Spatial Processing T-scores at 3-month follow up.*

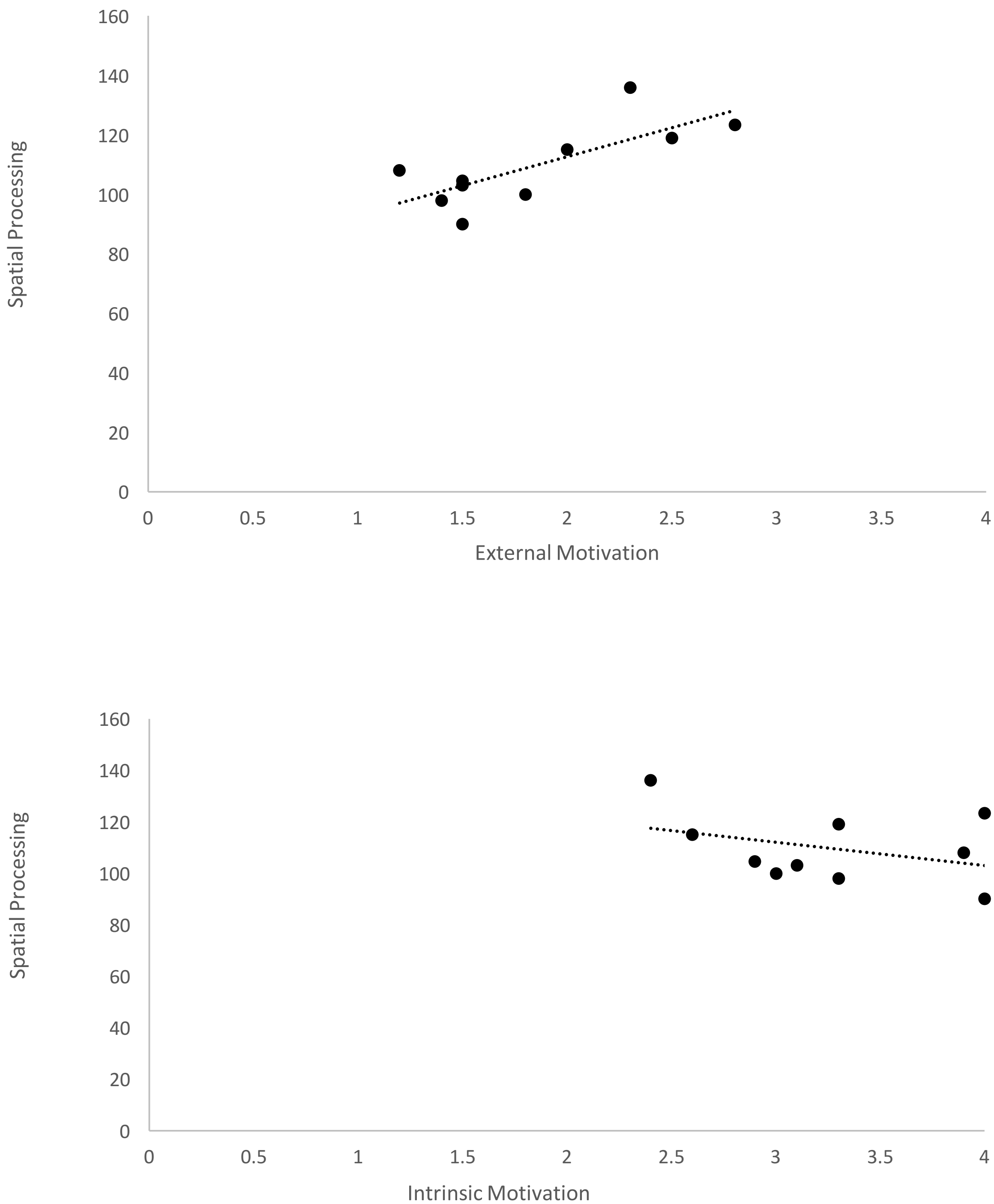
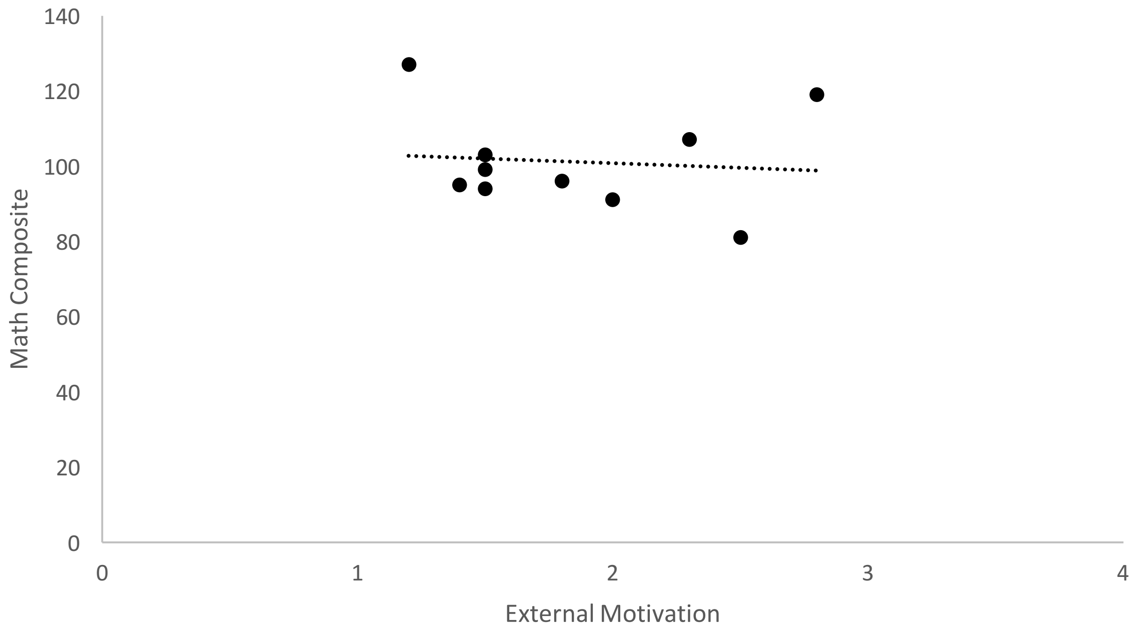


Figure 3. *Scatterplots of intrinsic and external motivation with WIAT-III math composite standard scores at 3-month follow up.*



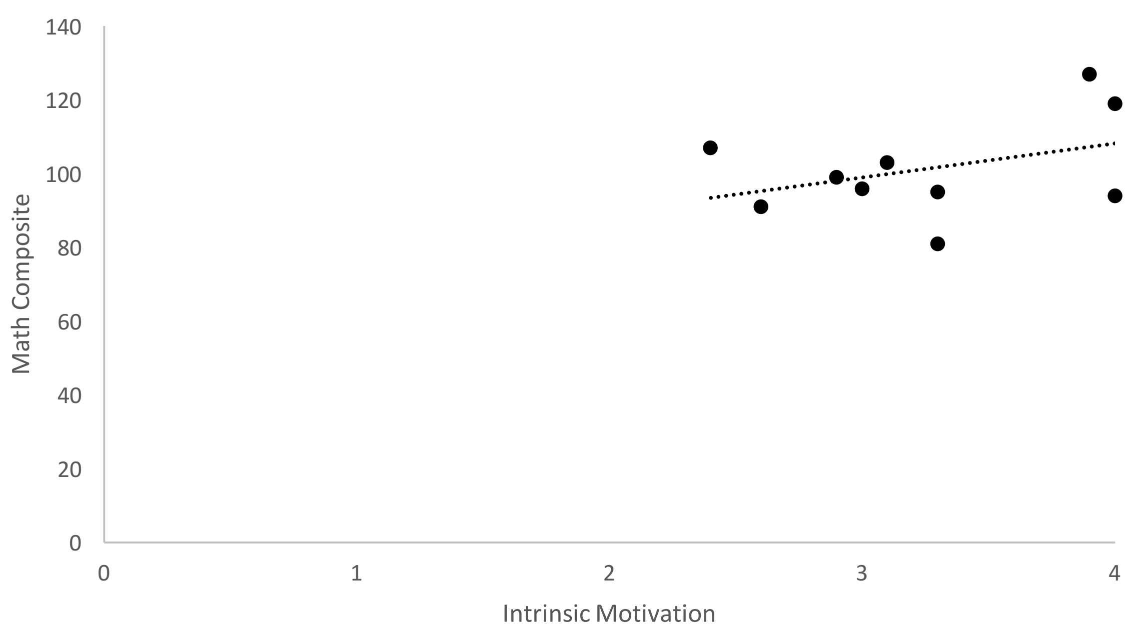
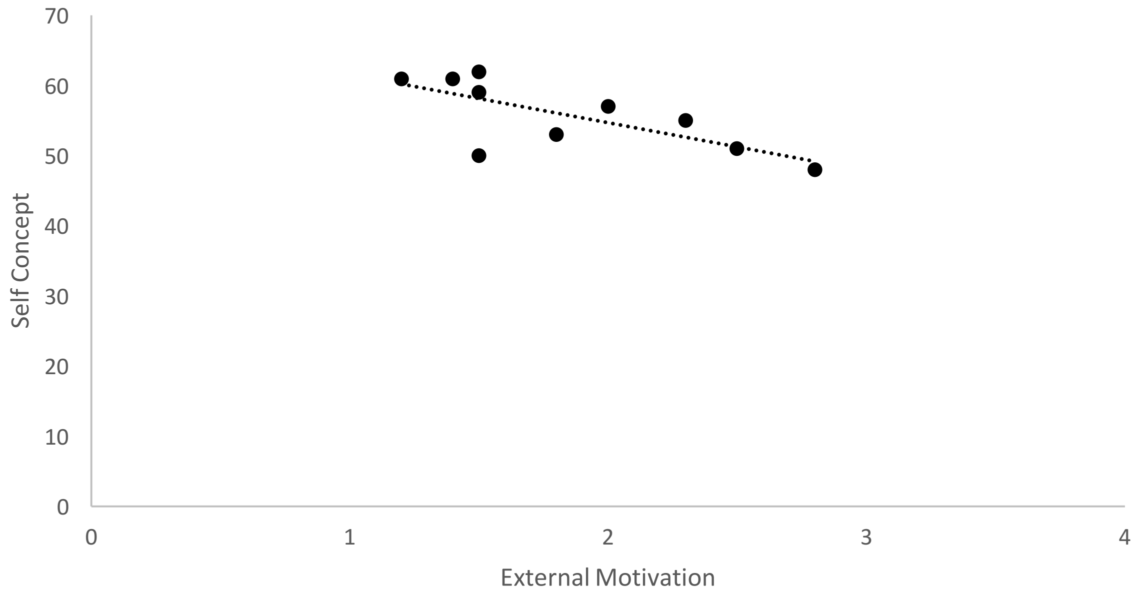


Figure 4. *Scatterplots of intrinsic and external motivation with BYI-II self-concept T-scores.*



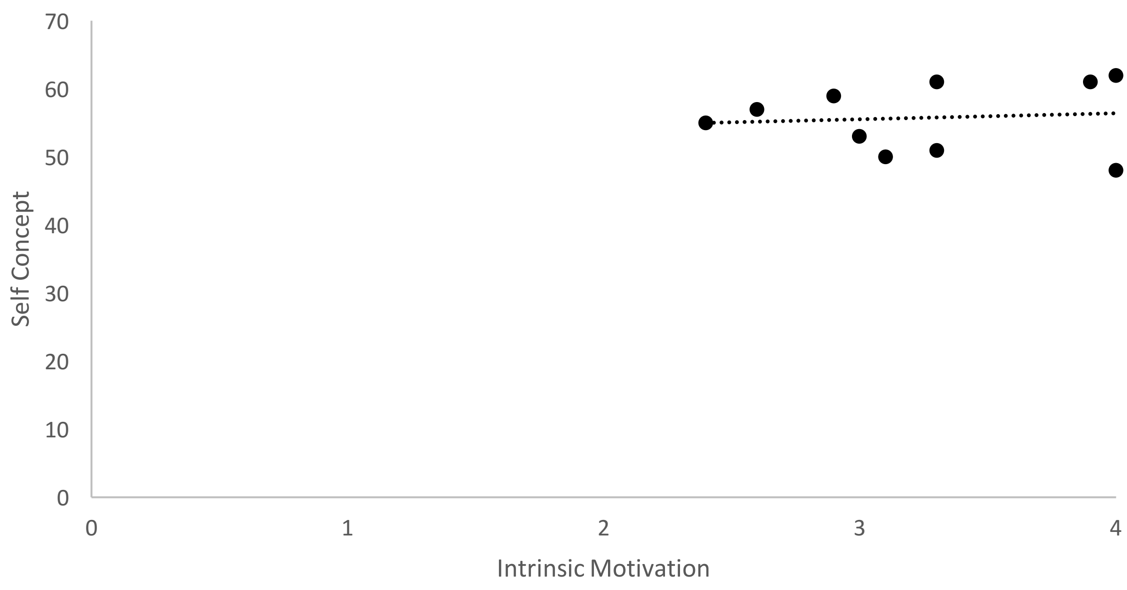
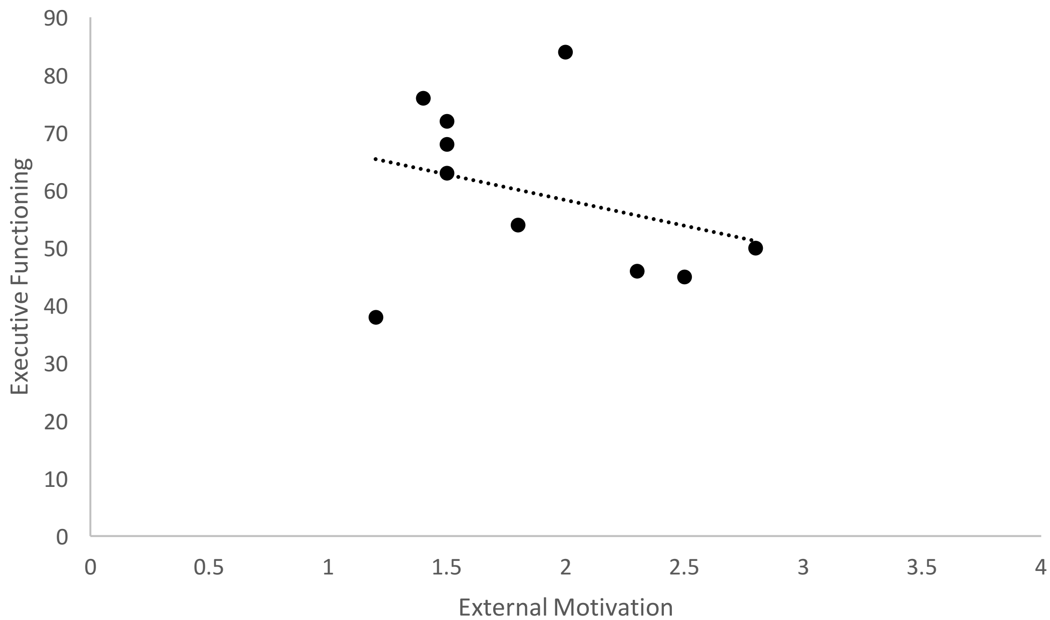


Figure 5. *Scatterplots of intrinsic and external motivation with teacher ratings (T-scores) on the BRIEF GEC.*



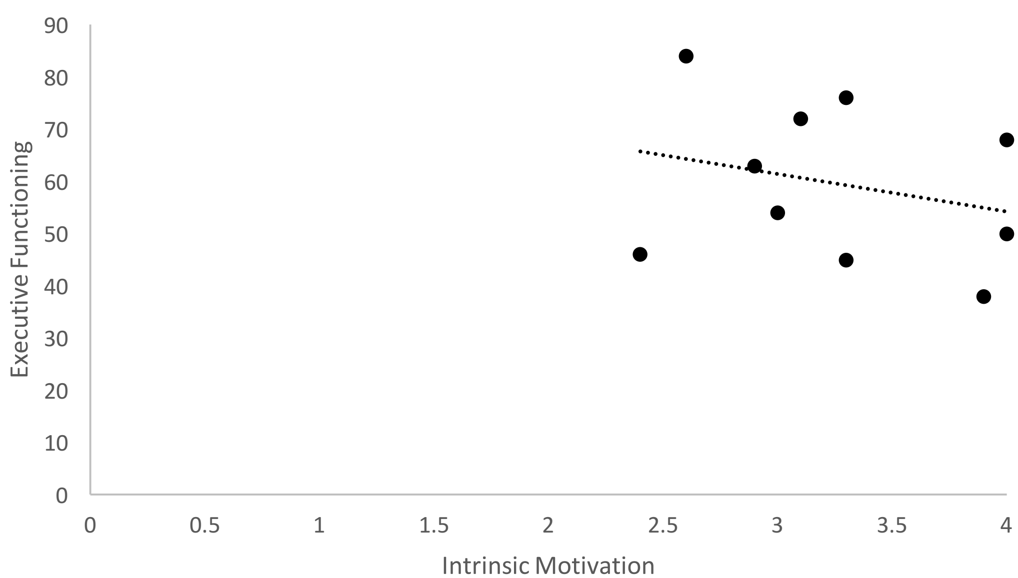
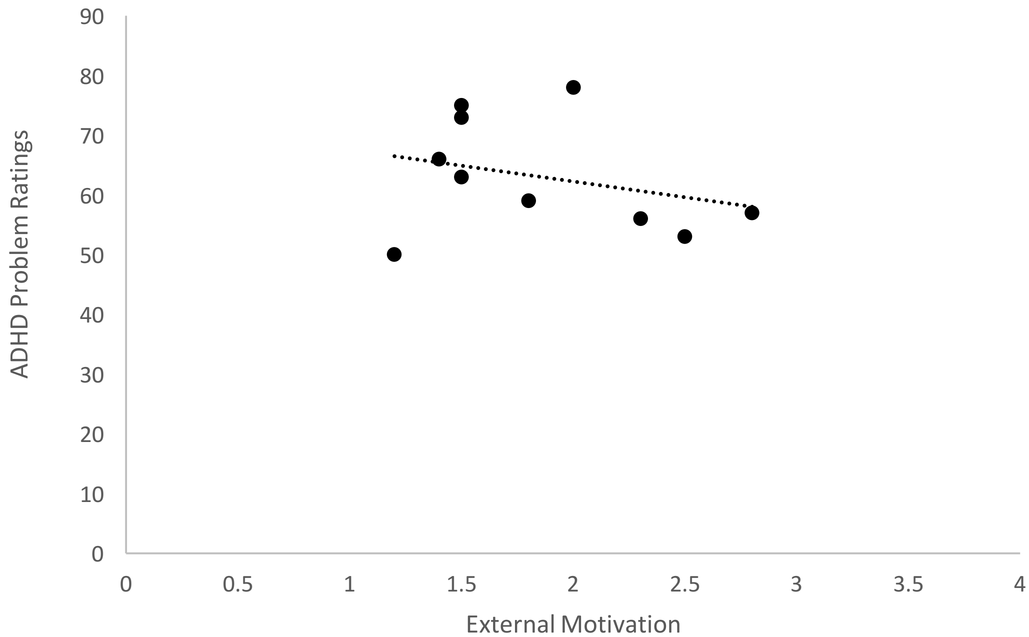


Figure 6. *Scatterplots of intrinsic and external motivation with teacher ratings (T-scores) on the TRF ADHD problems.*



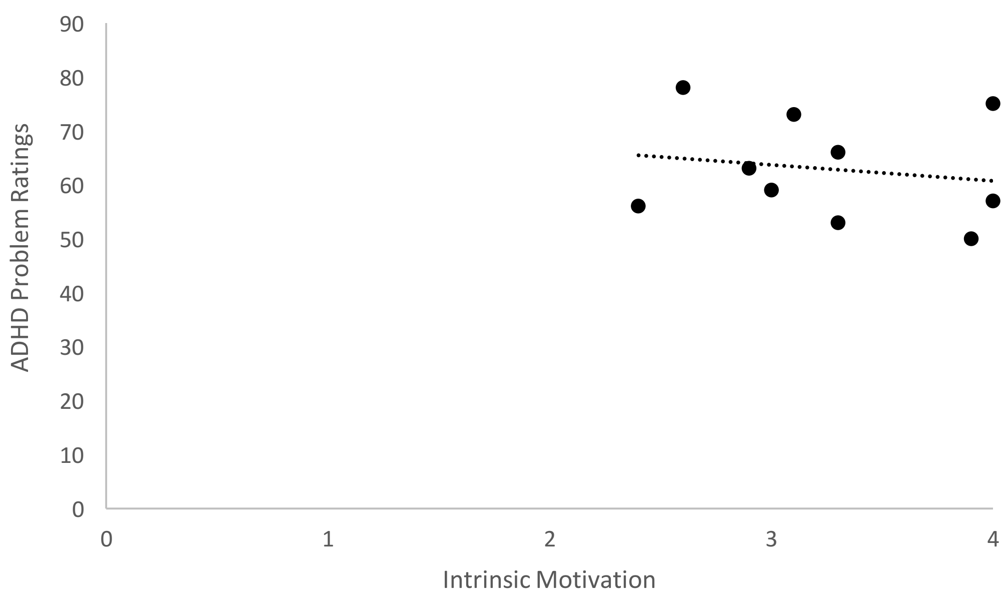


Figure 7. *Scatterplots of intrinsic and external motivation with parent ratings (T-scores) on the BRIEF GEC.*

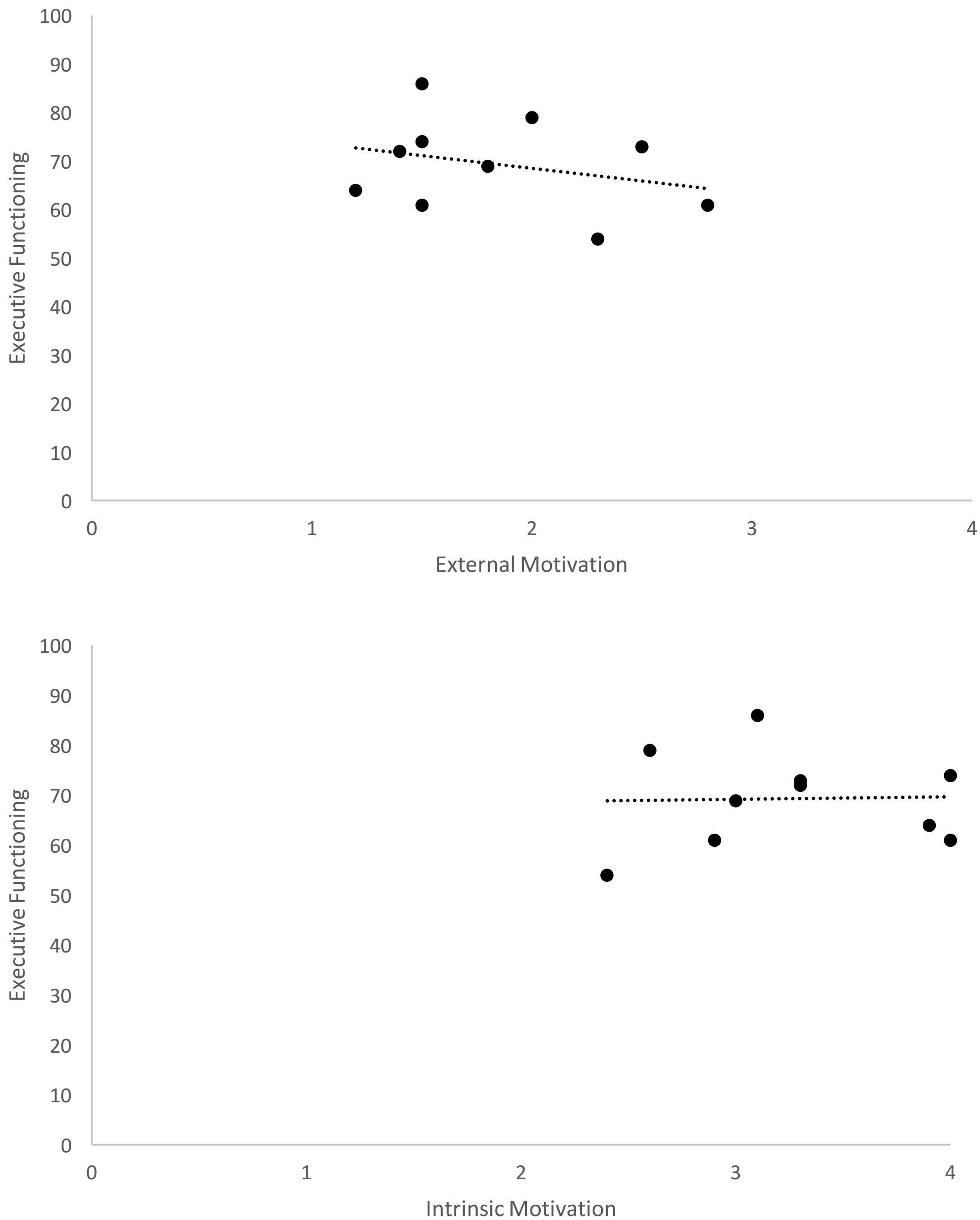
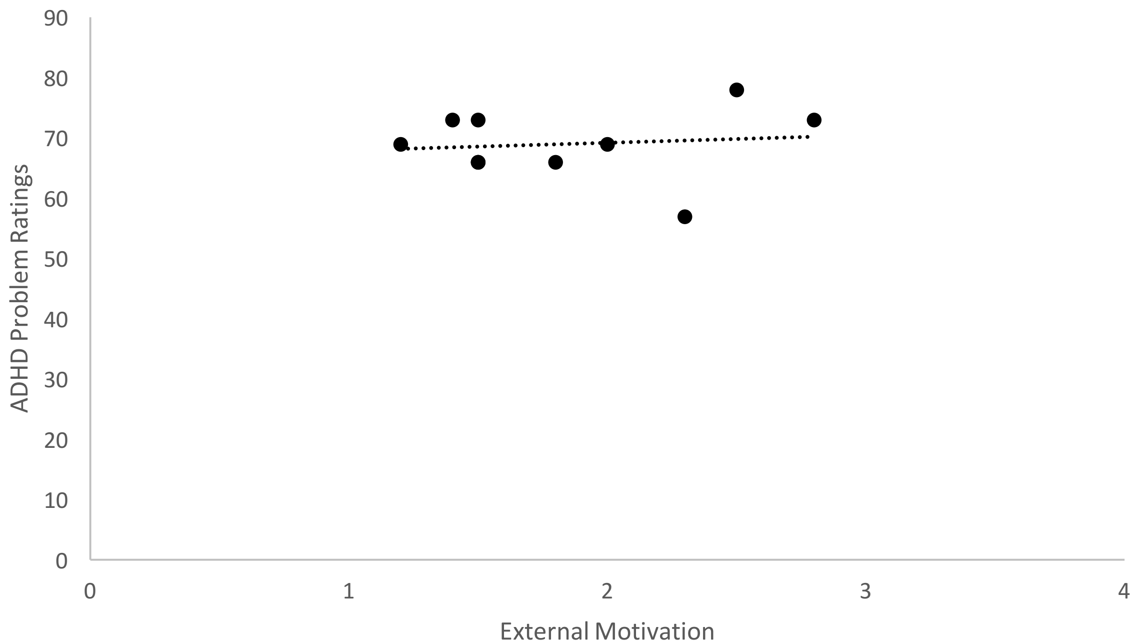


Figure 8. *Scatterplots of intrinsic and external motivation with parent ratings (T-scores) on the CBCL ADHD problems.*



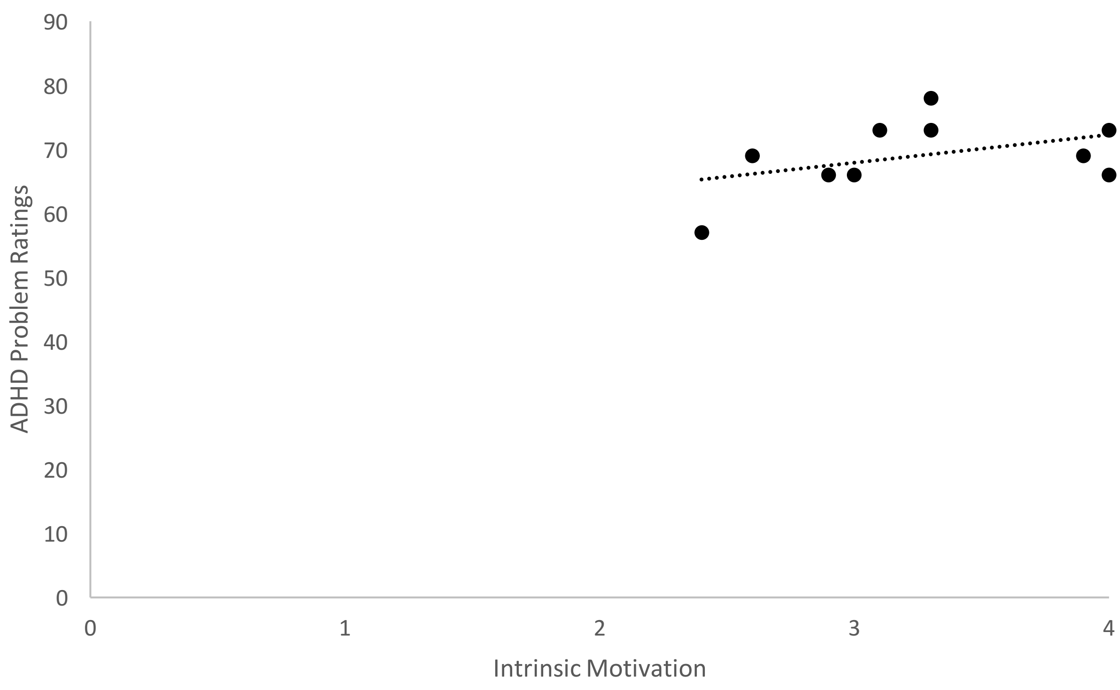


Table 1. *Independent Sample t-tests Comparing Clinical Variables, Cogmed Indices, and Outcome Measures for Cycle 1 and 2 Youth.*

	Cycle One *M (SD)*	Cycle Two *M (SD)*	*t*	*p*	95% CI	*d*
Demographics						
Age at Baseline	12.08 (2.75)	11.03 (1.74)	1.02	.323	[-1.12, 3.21]	0.46
CADDRA Symptoms						
Inattention	7.50 (1.51)	7.60 (0.97)	< 1	.862	[-1.29, 1.09]	0.08
Hyperactivity/impulsivity	6.00 (3.16)	6.80 (2.10)	< 1	.513	[-3.32, 1.72]	0.30
ODD	3.60 (3.03)	3.60 (2.32)	< 1	.999	[-2.53, 2.53]	0
Cogmed Indices						
Start Index	75.30 (9.08)	81.70 (11.41)	1.39	.182	[-16.09, 3.29]	0.62
Max Index	102.30 (14.01)	106.40 (13.03)	< 1	.507	[-16.81, 8.61]	0.30
*Cognitive Measures**						
WASI-II FSIQ	102.60 (15.18)	110.40 (12.87)	1.24	.231	[-21.02, 5.42]	0.11
WIAT-III Reading	96.90 (16.46)	103.30 (16.19)	< 1	.392	[-21.74, 8.94]	0.09
WIAT-III Mathematics	92.60 (12.14)	102.60 (14.56)	1.67	.113	[-22.60, 2.60]	0.75
AWMA Listening Processing	104.40 (17.85)	106.44 (19.46)	< 1	.810	[-19.59, 15.51]	0.11
AWMA Spatial Processing	93.77 (12.94)	101.89 (15.61)	1.27	.221	[-21.59, 5.35]	0.57
*Rating Scales**						
BYI Self Concept	48.30 (5.77)	48.90 (4.43)	<1	.797	[-5.44, 4.28]	0.12
CBCL ADHD	69.60 (4.86)	71.70 (6.62)	< 1	.429	[-7.55, 3.35]	0.36
TRF ADHD	61.40 (5.48)	62.80 (7.90)	< 1	.651	[-7.79, 4.99]	0.21
BRIEF2-Parent GEC	73.20 (8.99)	72.30 (8.67)	< 1	.822	[-7.40, 9.20]	0.10
BRIEF2-Teacher GEC	66.30 (10.09)	59.70 (9.11)	1.54	.142	[-2.43, 15.63]	0.69

*Note: Measures and scales as administered at baseline.

Table 2. *Pearson Correlations of Cogmed Indices with SRQ Scales*

	Correlation with Cogmed Index (r)		
SRQ Scale	M (SD)	Start	Max
External	1.85 (0.53)	.36	.42
Introjected	2.13 (0.53)	-.15	-.01
Identified	3.40 (0.54)	.09	-.07
Intrinsic	3.25 (0.57)	-.07	.07

Note. n = 10 youth from Cycle Two who completed the SRQ. $p > .36$ for all associations.

Table 3. *Pearson Correlations of SRQ Scales with Baseline and Follow-up Measures*

Measure		M (SD)	Correlation with SRQ Scale (*r*)			
			External	Introjected	Identified	Intrinsic
Baseline	AWMA Listening Processing	106.44 (19.46)	-.21	-.48	-.11	-.39
	AWMA Spatial Processing	101.89 (15.61)	.06	-.28	-.12	-.16
	WIAT-III Reading Composite	103.30 (16.19)	.45	-.33	-.45	-.04
	WIAT-III Math Composite	102.60 (14.56)	-.08	-.42	-.04	.25
	BRIEF2-Parent GEC	72.30 (8.67)	-.34	-.13	-.16	.14
	BRIEF2-Teacher GEC	59.70 (9.11)	-.41	-.09	-.12	-.33
	CBCL ADHD	71.70 (6.62)	-.26	-.23	.08	.50
	TRF ADHD	62.80 (7.90)	-.41	.03	-.02	-.21
	BYI Self Concept	48.90 (4.43)	-.03	-.54	-.31	.09
Post 2 Follow-up	AWMA Listening Processing	109.22 (15.13)	-.08	.01	.07	-.47
	AWMA Spatial Processing	109.68 (13.70)	.76*	.22	-.15	-.38
	WIAT-III Reading Composite	108.30 (12.98)	-.02	-.71*	-.74*	-.45
	WIAT-III Math Composite	101.20 (13.56)	-.10	-.40	.24	.39
	BRIEF2-Parent GEC	69.30 (9.52)	-.29	.14	-.26	.03
	BRIEF2-Teacher GEC	59.60 (15.23)	-.31	-.14	-.34	-.27
	CBCL ADHD	68.50 (5.66)	.19	.20	.07	.48
	TRF ADHD	63.00 (9.71)	-.29	.01	-.34	-.27
	BYI Self Concept	55.70 (5.06)	-.73*	-.32	.39	.10

*$p < .05$

Table 4. *Themes and Sample Quotes That Emerged From Post-Training Interviews.*

Theme		*n*	Sample quote
Reasons For Training	To improve memory	7	*"At my house, my mom would ask me to do something, I would quickly forget about it."*
	To improve focus/pay attention	8	*"Sometimes when someone says something to me, the moment they stop talking to me I'm like, what did you say?"*
	To reduce ADHD symptoms	3	*"I don't want to have ADHD, its hard."*
	To engage in a challenging activity	3	*"Helping myself and being able to learn and teach myself."*
	To improve organization	3	*"I play hockey, so before getting my equipment in the change room I would just start talking and be late for the ice."*
	To help others with ADHD	2	*"Because I would help other kids."*
Subjective Changes Post-Training	Improved Cogmed scores	7	*"I think I did really well in the game that you had to complete."*
	Improved Focus	6	*"I felt like I was more aware of what I was doing because of the programs. Because they make you sit down and think about what you're doing."*
	Improved memory	6	*"I remember in the morning when my mom gives me a list of chores to do in the afternoon."*
	Improvements in specific goals set out before training, including improved grades, math skills, or organization	7	*"My grades have improved a lot."*
Supports/Rewards Used for Training	Internal motivation	6	*"Having the determination to come in every day."*
	Gift received (iPad)	6	*"I thought I would really like the iPad."*
	Parents, Cogmed coach, or school teacher	6	*"When [my coach] was encouraging me that was nice of him. And that also encouraged me to keep going."*
	Enjoyment of program	6	*"I just thought it would be fun."*
	Food or activity reward	2	*"We'd get a donut. But not every single time."*

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Appendix A.
List of Cogmed RM Tasks

Exercises can be done in any order chosen by the participant, for a total of 8 exercises completed per training session. The following is a description of each of the 12 total Cogmed RM exercises, provided by Pearson (retrieved from cogmed.com):

Visuo-Spatial Exercises
Visual Data Link
A number of lamps are highlighted in succession. The participant needs to remember the order in which they came on. When the program says, “Your turn’’, the participant clicks on the lamps in the same order.

Sorter
Certain boxes will light up and numbers will be revealed. Then, the numbers will disappear. The participant must click on the boxes that lit up in numerical order.

Asteroids
A number of moving asteroids light up in succession. The participant needs to remember the order in which the shapes lit up. When the program says, “Your turn”, the participant clicks on the shapes in the same order they lit up.

Rotating Dots
The participant will see circles rotating. The circles will light up in certain order. The circles will continue moving, so the participant needs to keep track of the positions where the circles lit up. The participant then clicks on the circles in the same order that they appeared, even though they are now in new positions.

Rotating Data Link
A number of lamps are highlighted in succession. The participant needs to remember the order in which they came on. Before the participant provides an answer, the entire panel rotates 90 degrees. When the program says, “Your turn”, the participant clicks on the circles in the same order in which they came on, but has to remember that the panel has rotated 90 degrees. The participant has to click on the circles in the correct order, although they are now in new positions.

3D Cube
A number of panels will light up in a particular order. The participant needs to remember the order in which the panels lit up and click on the panels in the forward order.

Data Room
Some of the lamps in a 3-dimensional room light up. The participant needs to remember the order and then click on the lamps in the order that they lit up.

Space Whack
Monsters randomly appear in craters, but before they appear, they let out a little cloud of gas. The participant needs to remember the order of the gas clouds to be able to prepare to hit the

monsters over the head when they do appear.

Auditory Exercises

Stabilizer

Certain letters are read aloud. When a letter is read, it is displayed in the middle of a circle, and at the same time, a corresponding light is lit. After all the letters have been read, one of them will be displayed once again in the middle. The participant needs to remember which light came on when he/she heard that particular letter. The participant responds by clicking on the correct light.

Decoder

Certain letters are read aloud, and at the same time, the letter lights up. The participant needs to remember the letters he/she hears and then select the letters by clicking on them. For example, if the letters heard were, "D, P, E", the first letter was 'D' so the participant would have to select that letter from the three options next to the first light. At the next light, he/she would select 'P', the second letter. Finally, he/she would select 'E' from the options next to the third light. Of note, Decoder is only offered during sessions 1-5 of computer training.

Input Module

A number of digits are read out loud in succession. The participant needs to listen carefully and try to remember the order in which they were read. When the program says, "Your turn", the participant should click on the numbered buttons in reverse order. For example, if the digits, "3,7", were read out loud, the participant should click on '7' and then '3'.

Input Module with Lid

This is a different version of Input Module. The numbers are read out loud, however, the participant cannot see the numbered buttons as they are read (i.e., a lid comes down and covers them). The numbers will appear when it is the participant's turn to click on the numbered buttons in reverse order.

Appendix B.
Modified Self-Regulation Questionnaire

WHY I COMPLETED COGMED

INSTRUCTIONS: I am going to read you some questions about why you completed this training program. Each question has 5 answer choices, which are on this sheet of paper for you to look at. The answer choices are **Very true, Sort of true, Not very true, Not true at all,** or **I don't want to answer.** There are no right or wrong answers to these questions – just pick the choice that feels most true for you.

A. The first set of questions ask about why you did the training program. I did the training program because…

1. I wanted my parents/coach/teacher to think I'm a good student.
2. I would have gotten into trouble if I didn't.
3. It was fun.
4. I would've felt bad about myself if I didn't do it.
5. I wanted to get better.
6. I was supposed to do it.
7. I enjoyed doing my training.
8. It was important to me to do my training.

B. These next questions ask about why you finished each exercise, or game, in your training sessions. I finished each exercise because…

9. I didn't want my parents/coach/teacher to be upset with me.
10. I wanted my parents/coach/teacher to think I'm a good student.
11. I wanted to learn new things.
12. I would've felt badly about myself if I didn't.
13. It was fun.
14. Because that's the rule.
15. I enjoyed doing them.

16. It was important to me to work on the exercises.

C. Now I'm going to ask you some questions about why you tried to do the hard things in the exercises, or games. I tried to do hard things in the exercises because…

1. I wanted others to think I'm smart.
2. I feel badly about myself when I don't try.
3. I enjoyed doing the hard things.
4. That's what I'm supposed to do.
5. I wanted to see if I could do it.
6. It was fun to answer hard questions.
7. It was important to me to try to answer hard questions.
8. Because I wanted my parents/coach/teacher to say nice things about me.

D. In this last part I'm going to ask you some questions about why you tried to do well in the training program overall. I tried to do well overall because…

9. That's what I'm supposed to do.
10. I wanted my parents/coach/teacher to think I'm a good student.
11. I enjoyed doing the training well.
12. I would get in trouble if I didn't do well.
13. I would've felt badly about myself if I didn't do well.
14. It was important to me to try to do well in training.
15. I would feel proud of myself if I did well.
16. I might get a reward if I did well.

Appendix C.

Motivation Interview Questions

INSTRUCTIONS: Thank you for answering those questions. Now I would like to learn more about you and the training program. There are no right or wrong answers, and for any question you can tell me if you don't want to answer.

1) What were some reasons you chose to do the training?

2) What were some changes you hoped to make through the training?

3) Were you successful?

4) What is different now that you've completed the training?

5) What helped make the training happen?

Appendix D.

Raw Score Changes on Outcome Measures for Cycle Two Youth (*n* = 10)

	Baseline	Post 1	Post 2
	M (SD)	*M (SD)*	*M (SD)*
WIAT Math Composite	195.65 (25.90)	194.75 (23.82)	195.05 (25.54)
AWMA Spatial Recall Processing	43.30 (19.81)	68.65 (41.23)	63.50 (37.85)
BYI Self Concept	41.00 (5.42)	45.15 (4.85)	47.10 (5.44)
TRF ADHD Problems	13.85 (6.40)	11.50 (6.30)	12.60 (7.02)
BRIEF2-Teacher GEC	116.55 (24.90)	112.15 (27.24)	109.65 (31.05)
CBCL ADHD Problems	10.45 (2.21)	9.20 (2.82)	8.60 (3.27)
BRIEF2-Parent GEC	141.15 (18.34)	133.00 (19.88)	127.35 (22.09)