The Association between Neuropsychological Functioning and Cognitive Engagement and Their Associations with Reading Achievement in Pediatric Brain Tumor Survivors

A Thesis

Submitted to the Faculty of

Drexel University

by

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In partial fulfillment of the

requirements for the degree

of

Master of Science in Psychology

May 2015

Drexel UNIVERSITY

Acknowledgements

I am sincerely grateful for the support of my faculty advisor, Dr. Brian Daly and mentor at the Children's Hospital of Philadelphia, Dr. Matt Hocking, in designing and preparing this proposal. Also, I would like extend my deepest gratitude towards Drs. Dave DeMatteo and Jennifer Mautone for their willingness to provide guidance and help in the preparation of this project. Lastly, I would like to thank my lab members at Drexel and CHOP for their support. In particular, I would like to thank Mark McCurdy for assisting in administering the study protocol and Lauren Quast for coordinating and scheduling participants.

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Abstract

The Association between Neuropsychological Functioning and Cognitive Engagement and Their Associations with Reading Achievement in Pediatric Brain Tumor Survivors
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Background: Survivorship rates in children with pediatric brain tumors have increased over the last few decades. During the same time period there has been a dramatic increase in the presence of cognitive late effects in survivors (Landier et al., 2004). Neuropsychological late effects are demonstrated across a variety cognitive abilities and may be responsible for impairments in academic functioning seen in survivors (Robinson et al., 2010). Declines in pediatric brain tumor survivors' academic achievement include a variety of subjects such as math, spelling and reading; however, reading ability is more vulnerable to impairment in this population (Mabbott et al., 2005). In healthy peers, reading achievement is predicted by a variety of neuropsychological processes that survivors often demonstrate deficits in, including intelligence, attention, processing speed, working memory and executive functioning (Best, Miller, & Naglieri, 2011; Evans, Floyd, McGrew, & Leforgee, 2001). While an established link exists between neurocognitive functioning and reading achievement, little is known about how cognitive functioning specifically impacts reading ability. Rose (2005) theorized that cognitive functioning impairs learning if one is unable to use skillful strategies in order to recognize, interpret or select important incoming information. This theory is conceptually related to cognitive engagement, a derivative of school engagement that involves cognitive strategies used during learning (Greene, Miller, Crowson, Duke, & Akey, 2004).

Aims: The current study examined the association between neuropsychological functioning and reading achievement in children that recently completed treatment for a brain tumor. More specifically, the study examined associations between working memory, executive functioning and reading achievement. Additionally, indirect effects of working memory and executive functioning on reading achievement through cognitive engagement were evaluated.

Methods: This study utilized data collected as part of a longitudinal study of pediatric brain tumor survivors following the completion of tumor-directed treatment. The study sought to identify associations between survivor neuropsychological functioning and indicators of survivor, caregiver and family functioning. Child participants completed a neuropsychological assessment battery along with psychosocial measures immediately following completion of tumor-directed treatment, then at 6 months post-treatment, and again at 1 year post-treatment. Caregivers completed neurobehavioral and psychosocial questionnaires.

Results: Lower executive function abilities as assessed by parent-report significantly predicted reduced use of rehearsal- and organization-based cognitive strategies for learning. In contrast, working memory did not reveal any associations with cognitive engagement. Neither overall, nor strategy specific, cognitive engagement mediated the association between executive functioning/working memory and reading achievement.

Conclusions: Pediatric brain tumor survivors who display difficulties in executive functioning may also exhibit less use of rehearsal- and organization-based cognitive

learning strategies. Coaching of learning strategies implemented by teachers may prove useful in promoting the use of other advantageous learning strategies (e.g., elaboration and critical thinking), and also suppress the use of shallow learning strategies (rehearsal).

Chapter 1: Introduction

Tumors of the central nervous system (CNS) are the most common type of solid tumor in childhood and account for approximately 20% of all pediatric malignancies (Spiegler, Bouffet, Greenberg, Rutka, & Mabbott, 2004). Rates of diagnoses have increased over the past several decades with an estimated 4,300 children under the age of 20 being diagnosed annually (American Brain Tumor Association, 2012; American Cancer Society, 2014). This rise in prevalence is largely due to advances in neuroimaging, which have resulted in ease of visualization of brain tumors. Advances in treatment also are responsible for increased incidence of cures or remission, resulting in heightened survival rates; for example, 40-80% of children diagnosed with a brain tumor survive 5 years post-diagnosis (American Childhood Cancer Organization, 2014; Moore, 2005; 2008). Due to the increased likelihood of survival, short- and long-term adverse consequences of the tumor and treatment are increasingly important. These outcomes are often termed 'late-effects' and are by definition treatment-related sequelae that arise after completion of therapy and encompass physical, psychosocial, and cognitive consequences (Landier et al., 2004; Langeveld et al., 2003). This population is also more at risk for severe late-effects because of the increased aggressiveness of treatment, in particular cranial radiation therapy (CRT; Butler & Mulhern, 2005).

Late Effects in Pediatric Brain Tumor Survivors

Neurocognitive Late Effects

Due to the very nature of brain tumors as well as their treatment, child survivors are at risk for compromised neurocognitive status (Moore, 2005). Additional factors pertinent to pediatric brain tumor survivors that may contribute to cognitive late effects include neurological and preoperative factors, brain tumor location and age at diagnosis (Moore, 2005). Neurologic complications that enhance survivors' susceptibility to neurocognitive late effects encompass strokes, seizures, neuropathy, motor dysfunction as well as complications with the sensory system (Turner, Rey-Casserly, Liptak, & Chordas, 2009). Survivors are more vulnerable to impairments in neuropsychological functioning compared to non-CNS affecting cancers due to the increased aggressiveness of their treatment; cognitive declines are more significant when treatment includes CRT, which is hypothesized to be a result of damage to cortical and subcortical white matter caused directly by radiation (R. W. Butler & Mulhern, 2005; Moore, 2005). Survivors' impairments commonly arise 1 to 2 years following administration of treatment and display gradually over time (R. W. Butler & Mulhern, 2005).

While an array of neurocognitive deficits are exhibited in survivors, impairments in intelligence are most commonly demonstrated (Moore, 2005; Spiegler et al., 2004). Full Scale IQ (FSIQ), Verbal IQ (VIQ) and Performance IQ (PIQ) have been shown to be compromised in survivors, with a steeper decline shortly after treatment and a progressive leveling off over time (Moore, 2005; Spiegler et al., 2004). This progressive decline in IQ may be accounted for by a decrease in more narrow cognitive abilities (Conklin et al., 2012). Cognitive processes such as attention, processing speed, and working memory are viewed as foundational skills for one's ability to learn efficiently and retain material and are therefore considered indicators of IQ and academic achievement (Mulhern, Merchant, Gajjar, Reddick, & Kun, 2004).

Deficiencies in an array of core neuropsychological processes that may be responsible for negative changes in IQ and academic achievement are frequently seen in pediatric brain tumor survivors (R. W. Butler & Mulhern, 2005; Moore, 2005; Robinson et al., 2010; Spiegler et al., 2004). Survivors display an inability to filter their attention and execute tasks under conditions demanding attention. This attentional dysfunction has been confirmed across a variety of tumor locations and treatment modalities (R. W. Butler & Mulhern, 2005). Processing speed has also been shown to be a critical cognitive ability, with a large portion of age-related improvements in intelligence being accounted for by this function (Mulhern, Merchant, et al., 2004). Deficiencies in processing speed are exhibited in survivors of various tumor types and are correlated with radiation-induced hippocampal damage (Padovani, Andre, Constine, & Muracciole, 2012).

Survivors also demonstrate deficits in working memory, or the ability to temporarily retain and manipulate information (R. W. Butler & Mulhern, 2005; Palmer, 2008; Steinlin et al., 2003). Because working memory continues to develop after adolescence, pediatric brain tumor survivors are at greater risk for deficits in this neuropsychological process (Conklin et al., 2012). Working memory is particularly important as age-related improvements in IQ have also been shown to be partially accounted for by improvements in working memory (Conklin et al., 2012). Furthermore, working memory is linked to performance in math, spelling, reading and language and is associated with lower educational attainment (Ellenberg et al., 2009). Pediatric brain tumor survivors perform significantly worse on tasks measuring working memory ability in comparison to healthy peers and child survivors of non-CNS effecting solid tumors (Conklin et al., 2012). Deterioration of white matter in cerebello-thalamo-cerebral connections have been associated with working memory impairments in survivors of posterior fossa tumors treated with CRT (Padovani et al., 2012).

Working memory is often considered to be encompassed by executive functioning, an umbrella term used to define a range of cognitive processes which are integrated to perform goal oriented behavior (Chan, Shum, Toulopoulou, & Chen, 2008). In addition to working memory, survivors of a variety of ages, diagnoses and treatment types exhibit impairments in selective attention, metacognition, planning and cognitive flexibility (Wolfe et al., 2013). In addition to these elements of executive functioning, medulloblastoma survivors also display difficulties with organization and problem solving as measured by the Wisconsin Card Sorting Task (WCST) and the Trail Making Test Part B (Maddrey et al., 2005). Executive functioning skills have demonstrated a trend of continual decrease as time from diagnosis increases with more severe impairments associated with CRT (Spiegler et al., 2004; Wolfe et al., 2013). Findings indicate that executive dysfunction is correlated with reduced white matter volume in pediatric brain tumor survivors who have undergone CRT or were exposed to certain chemotherapeutic agents (Reddick et al., 2003).

Psychosocial Late Effects

Late effects seen in pediatric brain tumor survivors encompass a range of psychosocial consequences, including quality of life, maladjustment and social dysfunction (Turner et al., 2009). Compared with healthy peers and other pediatric cancer survivors, pediatric brain tumor survivors rate themselves significantly lower in health-related quality of life (HRQL; Macartney, Harrison, VanDenKerkhof, Stacey, & McCarthy, 2014). Additionally, compared to healthy peers, survivors' HRQOL is poorer in motor, cognitive and social domains (Macartney et al., 2014). Adjustment problems arise in survivors as medical and physical complications interact with expectations and challenges of one's particular developmental period (Turner et al., 2009). In particular, survivors demonstrate problems with social adjustment, defined by the quality of one's social interactions (Schulte & Barrera, 2010). Further, survivors are more prone to social incompetency and isolation, as these individuals demonstrate fewer social skills and interactions compared to healthy peers (Fuemmeler, Elkin, & Mullins, 2002).

Educational Achievement in Pediatric Brain Tumor Survivors

Adaptive outcomes in survivors are strongly influenced by neurocognitive late effects. For example, survivors display problems associated with employment, household income and, most commonly, educational achievement. Decreased levels of educational attainment for high school and fewer advanced graduate degrees frequently occur in this population (Langeveld et al., 2003; Mabbott et al., 2005). Further, educational attainment levels in pediatric brain tumor survivors are significantly lower than other CNS affecting cancers (e.g., leukemia; Langeveld et al., 2003). Compared with healthy controls, survivors are significantly less able to follow normal primary and secondary school courses and consequently end up in learning disabled or special education programs (Fouladi et al., 2005; Langeveld et al., 2003). Likelihood of intellectual disability in survivors is highly associated with CRT. For instance, Fouladi and colleagues (2005) found that 72% of survivors who received CRT under the age of three were later diagnosed with intellectual disabilities.

Poor academic achievement has been demonstrated as measured by parent-reports, teacher-reports and standardized measures across a variety of subjects, including math, reading and spelling (Conklin, Li, Xiong, Ogg, & Merchant, 2008; Mabbott et al., 2005; Ris et al., 2013). These impairments in school performance likely reflect a diminished rate of learning rather than a loss of previously attained skills or abilities (Moore, 2005; Mulhern, White, et al., 2004). This may account for the fact that younger age at diagnosis often results in greater declines in academic functioning, as these children may have missed early and critical instruction in learning skills (Conklin et al., 2008; Mabbott et al., 2005). Impairments in reading, math and spelling have been estimated to be one standard deviation below normative means, while mixed results exist regarding their rate of decline as time from diagnosis increases (Mabbott et al., 2005).

While some scholars suggest that both reading and arithmetic scores demonstrate a steeper decline as time from treatment increases, other literature indicates that reading skills are far more vulnerable than spelling or math (Conklin et al., 2008; Mabbott et al., 2005; Palmer, 2008). This may be explained by the fact that tumor directed treatment is associated with decreased white matter in the left temporo-parietal region, left temporal lobe and corona radiate. Together, these areas may contribute to reading achievement by integrating visual, auditory and language processing (Palmer et al., 2010). Research examining reading difficulties within this population rarely distinguishes impairments by the three core components of reading achievement: decoding, comprehension and fluency (Cirino et al., 2013). However, several studies show that pediatric brain tumor survivors exhibit deficits in both decoding and comprehension (Kieffer-Renaux et al., 2000; Reddick et al., 2003). Furthermore, decoding abilities are equally impaired among children who received reduced (csRT = 25Gy) and standard dose (csRT = 35Gy) whole brain irradiation, whereas comprehension skills are poorer among those receiving standard dosage (Kieffer-Renaux et al., 2000). This implies that level of treatment intensity for whole brain irradiation may influence impairments in reading comprehension, but not decoding skills. Last, longitudinal data indicates that decoding skills remain below normative samples for childhood brain tumor survivors as deficits have been identified in a range of six to greater than two years post treatment-completion (Kieffer-Renaux et al., 2000; Reeves et al., 2006; Smith, King, Jayakar, & Morris, 2014).

Neuropsychological Functioning and Academic Achievement

Healthy Children

In healthy children, intelligence is consistently the strongest predictor of educational achievement (Taub, Floyd, Keith, & McGrew, 2008). Full Scale IQ (FSIQ) as measured by the Wechsler Intelligence Scale for Children, Third Edition (WISC-III) has been shown to explain 52% of variance in achievement as measured by the Wechsler Individual Achievement Test (WIAT) and 58% of the variance as measured by the WIAT-II composite achievement test score (Mayes & Calhoun, 2007). Additionally, higher IQ is correlated with greater academic progress over the course of one's academic career (Mayes & Calhoun, 2007).

Despite such powerful relations between intelligence and academic functioning, additional neuropsychological constructs predict academic functioning in healthy peers, above and beyond intelligence (Evans et al., 2001; Floyd, Evans, & McGrew, 2003; Mayes & Calhoun, 2007). A large area of this research has examined Cattell-Horn-Carroll (CHC) Cognitive Abilities and their relation to math and reading abilities. CHC is the synthesis of two theories of intelligence that delineates a hierarchy of cognitive abilities with a placement of narrow cognitive abilities under broad cognitive ability domains (Taub et al., 2008). Cognitive abilities defined by the CHC theory significantly predict both math and reading achievement (Evans et al., 2001; Floyd et al., 2003; Taub et al., 2008). Specifically, math calculation skills are related to processing speed, long-term retrieval, comprehension-knowledge, fluid reasoning and working memory (Floyd et al., 2003; Taub et al., 2008). Math reasoning is associated with auditory processing, comprehension-knowledge, processing speed and working memory (Floyd et al., 2003). Furthermore, executive functioning is a strong predictor of concurrent and later math achievement beginning in preschool aged children (Bull & Lee, 2014). Specifically, working memory, set shifting, and inhibitory control also correlate strongly with math achievement measures (Clark, Sheffield, Wiebe, & Espy, 2013).

Similarly, CHC cognitive abilities and executive function are associated with reading achievement in healthy children. Reading skills demonstrate strong associations with comprehension-knowledge, auditory processing, long-term retrieval, processing speed and working memory. These associations are particularly robust during the formative years of reading skill acquisition (Evans et al., 2001). Likewise, reading comprehension is correlated with comprehension-knowledge, auditory processing, long-term retrieval and processing speed (Evans et al., 2001). Strong relations between executive function and reading skills have been demonstrated for a wide range of ages. For example, planning was significantly correlated with all reading subtests of the Woodcock Johnson Psychoeducational Battery Revised (letter-word identification, passage comprehension, word attack and reading vocabulary) in a representative sample of children ages 5-17, indicating that it plays a critical role in all domains of reading abilities (Best et al., 2011). Additionally, auditory-verbal working memory has been connected with one’s ability to acquire new knowledge and skills within reading and language (Rogers, Hwang, Toplak, Weiss, & Tannock, 2011).

Cognitively Impaired Pediatric Populations

There is some evidence to indicate that cognitive deficits are linked to academic achievement in other pediatric populations with chronic health conditions (Fastenau et al., 2004; Mayes & Calhoun, 2007; Rogers et al., 2011). For example, Fastenau and colleagues (2004) found that verbal ability, executive skills and working memory significantly predict reading, writing and math in children with epilepsy. Furthermore, psychomotor skills are a significant predictor of reading and writing in the pediatric epilepsy population (Fastenau et al., 2004). Last, deficits in attention and auditory-verbal working memory are related to academic underachievement in adolescents with attention deficit/hyperactivity disorder (ADHD; Rogers et al., 2011).

Pediatric Brain Tumor Survivors

Studies of pediatric brain tumor survivors show that neuropsychological abilities account for differences in students' ability to learn and understand the academic curriculum (Taub et al., 2008). Lower educational attainment in survivors is associated with overall cognitive ability as well as impairments in task efficiency, emotion regulation and memory (Ellenberg et al., 2009).

Neuropsychological Functioning and Learning

While associations between neuropsychological functioning and academic achievement are well established, little is known about the exact mechanisms in which neurocognitive deficits impact academic functioning. However, a clear pattern exists across many pediatric populations in which declines in cognitive abilities result in decreases in academic performance (Ellenberg et al., 2009; Fastenau et al., 2004; Mulhern, Merchant, et al., 2004; Rogers et al., 2011). It is speculated that such educational problems are due to a decline in a rate of learning arising from neuropsychological dysfunction, rather than from a loss of previously acquired knowledge in school (Mulhern, Merchant, et al., 2004).

Rose (2005) proposes a theory that connects neuropsychological functioning to learning by describing three systems of cognition that must integrate in order to learn new information and skills. First, the recognition system involves the posterior portion of the cerebral cortex and involves one’s ability to recognize items or patterns previously learned (Rose, 2005). Next, the strategic system encompasses the anterior part of the brain, in particular the frontal lobes, and contains the role of knowing how to skillfully and strategically interpret novel, incoming information. One example is knowing how to interpret new text during reading in a meaningful manner (Rose, 2005). Last, the affective system allows one to determine the importance of information gathered; this system is crucial to learning in that it allows us to decide what incoming information is worth storing in long-term memory (Rose, 2005). In order to produce successful learning, these three systems must interact and any weakness in one may result in learning impairments (Rose, 2005).

Cognitive Engagement

The three systems of cognition described in Rose’s (2005) theory are conceptually related to cognitive engagement, or cognitive strategy use during learning (Greene et al., 2004). Cognitive engagement is a subset of school engagement, a multi-component concept that delineates identification with the social and academic aspects of school (Norris, Pignal, & Lipps, 2003). School engagement is typically divided into three different elements, each representing a unique way in which the student can actively participate in school-related activities: behavioral, emotional and cognitive engagement (Fredricks, Blumenfeld, & Paris, 2004). First, behavioral engagement includes involvement in academic or social and extra-curricular activities, such as athletics or student government. Involvement in these events is considered to be critical for preventing educational failure and drop out (Fredricks et al., 2004). Second, emotional engagement involves the students' affective reactions to instructors and peers. This is believed to create connections to the institution and may influence the students' willingness to do school work (Fredricks et al., 2004). Last, cognitive engagement encompasses the cognitive strategies students use when learning course material (Greene et al., 2004).

The cognitive concept represents a psychological investment in learning and has multiple subdivisions that can be more broadly described as either deep or shallow strategies (Fredricks et al., 2004; Greene et al., 2004). These strategies vary and include rehearsal, elaboration, critical thinking and organization (Pintrich & De Groot, 1990). Deep strategies indicate that a student is using higher levels of cognitive engagement and is therefore creating more connections among information being learned to achieve greater knowledge regarding the subject (Fredricks et al., 2004). Elaboration, organization and critical thinking all demonstrate meaningful strategy use during learning. Elaboration involves the summarization of important information and the storing of that material into long term memory (Burlison, Murphy, & Dwyer, 2009). Organization encompasses strategies for selecting meaningful information by constructing connections and mental representations among to be learned material (Burlison et al., 2009). Critical thinking is the extent to which students apply this knowledge to new situations or to solve problems (Burlison et al., 2009). Alternatively, shallow strategies produce less intricate mental representations, limiting the student's ability to retrieve and connect this stored knowledge to new incoming information (Greene et al., 2004). Rehearsal is considered a shallow strategy that involves reciting information to be learned in order to better recall this material (Burlison et al., 2009). It has been suggested that cognitive engagement increases in children as they age, since it builds on itself once it has been established (Fredricks et al., 2004).

The strategic and affective systems of Rose's (2005) theory can both be conceptually related to cognitive engagement. First, the strategic system and cognitive engagement both involve using meaningful strategies to interpret incoming knowledge (Burlison et al., 2009; Rose, 2005). While elaboration allows one to summarize information skillfully so that one is able to better understand what he or she is learning, organization involves strategies of better representing the information summarized (Burlison et al., 2009). Next, the affective system and organization are similar in that each that allows one to determine whether the information presented is important enough to be connected with already stored knowledge (Burlison et al., 2009; Rose, 2005).

Cognitive Engagement and Neuropsychological Functioning

Evidence relating cognitive engagement to both neurocognitive functioning and academic achievement further support the idea that cognitive engagement may act as a mediator between the two constructs. First, rehearsal, elaboration and organization have been found to be significantly predicted by several aspects of executive function: planning, impulse control, motivational drive and empathy (Garner, 2009). This finding implies that deficits in executive functioning and cognitive strategy use may arise from the same brain regions. Additionally, it suggests that executive dysfunction may prevent students from being able to utilize cognitive strategies of rehearsal, elaboration and organization in the classroom (Garner, 2009).

Cognitive engagement and working memory have been shown to be related in children with TBI. Specifically, the ability to summarize text (elaboration) was shown to relate to working memory performance as measured by an N-Back task (Chapman et al., 2006). In addition to this finding, working memory and cognitive engagement are conceptually related. . Mayer (1996) describes the Selection, Organization and Integration (SOI) model, which incorporates different types of memory into strategies needed for meaningful learning. First, one must select which information is important and which information is irrelevant by pulling the meaningful information presented from sensory memory and placing it in working memory. While this information is stored in working memory, it is organized in such a way that a coherent mental representation is formed. This structure of new knowledge is integrated with existing knowledge in long-term memory before being stored for long-term retrieval (Mayer, 1996). The three processes Mayer (1996) describes in his SOI model are heavily related to the specific cognitive strategies of elaboration and organization; the construction of a coherent structure involves both organization of the new information and the summarizing of what information is relevant for meaningful learning (Crede & Phillips, 2011).

Levels of cognitive engagement have yet to be studied within the pediatric brain tumor population; however, deficits within cognitive strategy use have been demonstrated in other pediatric and adult populations with neuropsychological impairments (Gamino, Chapman, & Cook, 2009; Roth et al., 2004; Stuss et al., 1994).

First, adolescents with mild or severe traumatic brain injuries (TBI) display shallow cognitive strategies rather than higher levels of cognitive engagement. These individuals exhibit increased rates of use of rehearsal compared to healthy controls and are more often unable to extract meaning from text, a skill related to elaboration and organization (Gamino et al., 2009). Adults with frontal lobe lesions demonstrate an inability to use organization during learning (Stuss et al., 1994). A lack of organizational strategy use can lead to impaired retrieval of learned information, an ability crucial for reciting course material and applying it to new information (Stuss et al., 1994). Similarly, adults with ADHD have exhibited lower levels or organizational strategy use compared with healthy controls (Roth et al., 2004). Both children and adolescents with ADHD demonstrate cognitive engagement deficits as seen by their failure to produce gist-based concepts from material, indicating an inability to extract meaning from course material (Gamino et al., 2009). This may imply difficulty in making connections between information presented and former knowledge and a failure to think critically about material.

Cognitive Engagement and Academic Achievement

Many studies have demonstrated a robust association between cognitive engagement and academics with cognitive strategy use predicting academic outcomes (Fredricks et al., 2004; Greene et al., 2004; Meece, Blumenfeld, & Hoyle, 1988; Pintrich & De Groot, 1990). Use of different cognitive strategies has been shown to result in different levels of learning, resulting in different achievement outcomes (Greene et al., 2004). Generally, students who employ more meaningful strategies (e.g. elaboration, organization, critical thinking) demonstrate enhanced performance on measures of achievement than those who exercise shallow strategies (e.g. rehearsal) (Walker, Greene,

& Mansell, 2006). Shallow strategy use has demonstrated negative associations with achievement and students who employ these low levels of cognitive engagement demonstrate poorer performance on achievement assessments (Greene et al., 2004; Pintrich & De Groot, 1990). Additionally, students who demonstrate a heavier emphasis on goals within academics report more active cognitive engagement during learning activities (Meece et al., 1988). These findings imply that students who use higher levels of cognitive strategy use during learning are likely to report higher levels of academic achievement and may be more goal-oriented within academics.

Cognitive engagement has a strong association with reading achievement. Both the amount of reading for enjoyment and for school requirements is predicted by cognitive engagement in school-aged children (Cox & Guthrie, 2001). Additionally, amount of time spent reading fiction and non-fiction texts was predicted from cognitive strategies for children ages 9, 13 and 17 years (Guthrie, Schafer, Wang, & Afflerbach, 1995). It is suggested that successful use of meaningful cognitive strategies enable students to understand text, therefore rewarding students' choice to read, and promoting future reading activities. This increase in reading activity would, in turn, improve one's reading abilities and lead to greater reading achievement in school (Guthrie et al., 1995).

Current Study

Rationale

Evidence demonstrates that neurocognitive late effects may play a large role in survivors' decline in academic functioning, as educational attainment has been found to be significantly predicted by poor cognitive performance in this population (Ellenberg et al., 2009; Mulhern, White, et al., 2004). Neuropsychological functioning has been linked to academic achievement in healthy peers as well as other cognitively compromised pediatric populations (Fastenau et al., 2004; Fouladi et al., 2005; Rogers et al., 2011). While little is known regarding the exact mechanisms in which neurocognitive performance affects academic achievement, it has been suggested that a decline in neuropsychological functioning decreases one's rate of learning which, in turn, negatively impacts school performance (Mulhern, White, et al., 2004). It has been proposed that cognitive functioning alters learning through integrated cognitive systems that together provide skillful strategies for interpreting incoming information (Rose, 2005).

Similar to these proposed systems is the concept of cognitive engagement, or cognitive strategy use during learning. Cognitive engagement, a subset of school engagement, involves both deep and shallow strategies to successfully learn novel information presented in the classroom (Fredricks et al., 2004). To further support the role of cognitive engagement as a mediator between neuropsychological functioning and academic achievement, cognitive engagement is related to both working memory and executive functioning and significantly predicts reading abilities (Cox & Guthrie, 2001; Garner, 2009; Mayer, 1996). As such, little is known about cognitive engagement in pediatric brain tumor survivors and its potential role as a mediator between either working memory and executive functioning and reading achievement.

Aims

The current study examined the associations between the neuropsychological domains of working memory and executive function, cognitive engagement and reading achievement in pediatric brain tumor survivors. This study also evaluated cognitive engagement as a possible mediator between working memory and/or executive functioning and reading achievement. This research has the potential to add to our understanding of reading achievement in pediatric brain tumor survivors and may stimulate additional research examining the interaction between cognitive engagement, neuropsychological functioning and academic achievement. In turn, findings from this research may contribute to the development of more effective curriculum and classroom adjustments and interventions for pediatric brain tumor survivors.

Hypotheses

The current study tested the following hypotheses regarding the associations between neuropsychological functioning, cognitive engagement and academic achievement among pediatric brain tumor survivors:

(1) Lower working memory and executive functioning will be significantly related to lower overall cognitive engagement independently, while controlling for IQ;

(2) Lower working memory and executive functioning will be significantly related to increased use of rehearsal learning strategies independently, while controlling for IQ. In turn, lower working memory and executive functioning will be significantly related to decreased use of elaboration, organization and critical thinking learning strategies independently, while controlling for IQ;

(3) Lower working memory and executive functioning will be significantly related to worse reading achievement independently, while controlling for IQ;

(4) Working memory and executive functioning will have indirect effects on reading achievement through overall cognitive engagement, rehearsal-,

elaboration-, organization- and critical thinking-based learning strategies, independently.

Chapter 2: Methods

This study utilized data collected as part of a longitudinal study conducted in the Division of Oncology at The Children's Hospital of Philadelphia (CHOP). The study was designed to identify associations between survivor neuropsychological functioning and indicators of survivor, caregiver and family functioning. Pediatric brain tumor survivors were administered a neuropsychological assessment battery along with psychosocial measures within 5 months of completing tumor-directed treatment and again 6 and 12 months later. Caregivers were administered neurobehavioral and psychosocial questionnaires.

Participants

Participants included 27 children and adolescents, ages 10-16 years (M = 12.97, SD = 1.71), transitioning off active medical treatment for pediatric brain tumor. The minimum age of 10 years was selected due to the lack of valid and reliable measures of cognitive engagement in children younger than 10 years of age. Also, the cut off of age of 16 years was chosen because of age restrictions of the Wechsler Intelligence Scale for Children- Fourth Edition (WISC-IV). Eligible survivors recently completed tumor-directed treatment, including any combination of surgical resection, chemotherapy, and cranial or cranial-spinal radiation, including proton beam therapy. Exclusion criteria for survivors for the parent study included: (1) a multi-system genetic condition that may affect neurocognitive function, (2) cognitive or developmental delays prior to brain tumor diagnosis, (3) only undergoing biopsy or only being monitored, and (4) non-English speaking. Eligible caregivers met the following criteria: (1) a parent/legal guardian, and (2) lives with the child at least 50% of the time. The majority of participants were female (63%). While the majority of the sample was Caucasian (77.8%), other participants identified as African-American (18.5%) and Hispanic/Latino (3.7%). On average, participants were diagnosed with a brain tumor at 10.54 years of age (*SD* = 2.87). A history of a variety of tumors were reported by caregivers, including: Low Grade Astrocytoma (33.3%), Low Grade Glioma (25.9%), Germinoma (11.1%), Ganglioglioma (11.1%), Medulloblastoma (7.4%), Ependymoma (3.7%), Meningioma (3.7%) and Germ Cell Tumor (3.7%). Participants also endorsed various treatment methods: Biopsy (66.7%), Resection (40.7%), Chemotherapy (44.4%), and Radiation therapy (29.6%). The caregiver sample ranged in age from 31 years to 53 years (*M* = 43.30, *SD* = 5.91) and consisted primarily of females (96.3%). Caregivers reported identifying with the following ethnicities: Caucasian (85.2%), African-American (11.1%) and Hispanic/Latino (3.7%). See Table 1 for full participant demographics.

Procedures

Recruitment for this study occurred as part of the ongoing parent study. Participants eligible for the study were identified by members of the CHOP Neuro-Oncology medical team as they prepared to complete treatment. Those children who were identified as eligible received a letter via mail describing the study in addition to information being discussed with medical staff. Research staff followed-up with identified potential participants either over the phone or in person at clinic appointments. After providing consent and assent, children and their caregiver completed designated measures simultaneously for a baseline assessment. Baseline occurred up until 5 months following completion of tumor-directed treatment. Measures were administered to the survivor in the following order: (1) Wechsler Abbreviated Scale of Intelligence, Second Edition (WASI-II) Vocabulary subtest, (2) Wechsler Abbreviated Scale of Intelligence, Second Edition (WASI-II) Matrix Reasoning subtest, and (3) WISC-IV Digit Span Backwards subtest. The caregiver completed a demographic questionnaire as well as the Behavior Rating Inventory of Executive Function (BRIEF) Parent Version. The measures administered at the second time point in the study, six months following baseline, were identical to those presented at baseline with the exclusion of the WASI-II Vocabulary and Matrix Reasoning subtests (see Table 2). These subtests were not re-administered at the second time point to avoid practice effects. Standards on practice effects for the remaining tests did not indicate any foreseeable problems with re-administration within a six month time frame. One year following baseline, participants were administered the full battery again to complete the third, and final, time point of the study.

An amendment to the study was successfully submitted to the hospital's Institutional Review Board to approve the administration of the Wide Range Achievement Test IV (WRAT-4) Word Reading subtest and the Motivated Strategies for Learning Questionnaire (MSLQ) Cognitive Strategy Use subtest. The WRAT-4 Word Reading subtest was administered directly following the WASI-II Vocabulary subtest whereas the MSLQ Cognitive Strategy Use subtest was preceded by the WISC-IV Digit Span Backwards Test. Administration of the WRAT-4 Word Reading subtest and the MSLQ Cognitive Strategy Use subtest occurred at one of the participant's three time points (see Table 2). If administered at the six month assessment, results from the following measures at this time point were used for data analyses in addition to the

WASI-II Vocabulary and WASI-II Matrix Reasoning subtests administered at baseline: (1) WISC-IV Digit Span Backwards Test, (2) BRIEF, (3) WRAT-4 Word Reading (4) MSLQ Cognitive Strategy Use. If administered at the one year assessment, all data was collected from this time point. Data collection occurred at multiple time points, rather than solely one time point, in order to achieve sufficient sample size for data analyses. Data was most frequently collected from participants' baseline assessment in the parent study (44.40%), while the remaining data was collected at the six month assessment (29.60%) and the one year assessment (25.90%).

Participants who had already completed their one year assessment and were not administered the WRAT-4 Word Reading subtest or MSLQ Cognitive Strategy Use subtest were contacted with the option to be administered these additional measures. These participants received the administration of the WRAT-4 Word Reading subtest or MSLQ Cognitive Strategy Use subtest at CHOP and this appointment coincided with other medical appoints at the hospital.

Measures

Demographic Questionnaire. A 42-item demographic questionnaire was created in order to assess relevant information regarding both the child and caregiver. Questions addressing information pertaining to the child included the following topics: age, gender, ethnicity, grade level, learning disabilities, educational services, missed school, diagnosis, treatment type and other medical conditions. Information collected regarding the caregiver included: age, gender, ethnicity, association status, association to survivor, occupation, annual income, level of education, religious preference and family medical history. Last, four questions were asked assessing the caregiver's opinions concerning his or her survivor's problems with thinking and learning.

Wechsler Abbreviated Scale of Intelligence Second Edition (WASI-II). The WASI-II (Wechsler, 2011) was developed to quickly assess cognitive intelligence and provides a brief estimate of verbal and nonverbal abilities in individuals ages 6-90 years. The measure yields four subtests: Vocabulary, Block Design, Similarities, and Matrix Reasoning. Either a two-subtest form of the WASI-II (i.e., Vocabulary and Matrix Reasoning) can provide an estimated Full-Scale IQ (FSIQ-2) or a four-subtest form of the WASI-II (Block Design Similarities, Vocabulary and Matrix Reasoning) can provide an estimated Full-Scale IQ (FSIQ-4). (Wechsler, 2011). The measure was standardized in a sample of 2,300 children and adults matched on age, gender and race/ethnicity with the 2008 U.S. census data. Internal consistency for the FSIQ-2 is 0.93 and 0.96 for the FSIQ-4 in the child sample (6-16 years). Test-retest reliability ranges from good to excellent for composites (0.87-0.95) and inter-rater reliability is high (0.98-0.99). Concurrent validity ranges from acceptable to excellent (0.71-0.92) as scores significantly correlate with the Wechsler Intelligence Scale for Children, Fourth Edition (WISC-IV) and the Wechsler Adult Intelligence Scale, Fourth Edition (WAIS-IV) (Wechsler, 2011). The FSIQ-2 was used as an estimate of overall intellectual abilities.

Wechsler Intelligence Scale for Children Fourth Edition (WISC-IV). The WISC-IV (Wechsler, 2003) is a widely used intelligence scale for children that contains 15 subscales taken together to yield a Full Scale IQ (FSIQ). The full battery includes a Verbal Comprehension Index (VCI), Perceptual Reasoning Index (PRI), Working Memory Index (WMI) and Processing Speed Index (PSI). Standardization of the WISC-

IV was completed with a sample of over 2,200 children matched closely to the 2002 U.S. census data on age, gender, geographic region, ethnicity and socioeconomic status (Kaufman, Flanagan, Alfonso, & Mascolo, 2006). The average internal consistency for all subtests was 0.94, with each subtest indicating good internal consistency: VCI (alpha = 0.94), PRI (alpha = 0.92), WMI (alpha = 0.88), PSI (alpha = 0.97) and FSIQ (alpha = 0.97). Good test-retest reliability has been shown (0.86-0.93) and construct validity with the WISC-III, Wechsler Preschool and Primary Scale of Intelligence, Third Edition (WPPSI-III), WAIS-III and Wechsler Individual Achievement Test, Second Edition (WIAT-II) is established (Kaufman et al., 2006). The Digit Span subtest involves two separate measures: Digit Span Forwards and Digit Span Backwards. Digit Span Forward requires the participant to repeat numbers in the same order as read aloud to him or her, measuring rote learning, memory, attention, encoding and auditory processing. Alternatively, the Digit Span Backwards task requires the child to repeat the numbers read aloud backwards, measuring working memory, transformation of information, mental manipulation and visuospatial imaging (Wechsler, 2003). The WISC-IV Digit Span Backwards scaled score was used to measure working memory.

Behavior Rating Inventory of Executive Function (BRIEF). The BRIEF (Gioia, Isquith, Guy, Kenworthy, & Baron, 2000) is a parent-report that assesses the everyday, behavioral aspects of executive function. It is a standardized 75-item self-report rating scale that yields nine theoretically and empirically derived subscales: Inhibit, Self-Monitor, Shift, Emotional Control, Initiate, Working Memory, Plan/Organize, Organization of Materials, and Monitor. These subscales are grouped to form two index scores: Behavioral Regulation Index (Inhibit, Shift, Emotional Control and Self-Monitor) and Metacognitive Index (Initiate, Working Memory, Plan/Organize, Task Monitor and Organization of Materials). Additionally, a total score (Global Executive Composite, GEC) is given (Rabin et al., 2006). The Metacognitive subscale was used in this study as it represents the child's ability to cognitively self-manage tasks and monitor task performance; these are concepts more theoretically related to neurocognitive functioning and cognitive strategy use (Gioia et al., 2000). Internal consistency for the Metacognitive subscale is excellent (alpha = 0.96). Additionally, the Metacognitive subtest has shown good test-retest reliability (0.88) and construct validity by demonstrating significant correlations with scores on the ADHD-Rating Scale-IV Inattention scale, Child Behavior Checklist Attention Problems, Teacher's Report Form and the Behavior Assessment System for Children – Parent and Teacher Rating Scales. Additionally, it has displayed clinical utility as an ecologically sensitive measure of executive functioning in both healthy youth and those with a range of neurological conditions (Roth et al., 2005).

Wide Range Achievement Test Fourth Edition (WRAT-4). The WRAT-4 (Wilkinson & Robertson, 2006) is designed to be a quick and sound assessment of academic skills in individuals ages 5-94 years. It is a single level test with alternate forms (blue and green) and yields three composite scores: Reading, Spelling and Mathematics. The reading composite is comprised of the Word Reading, Sentence Comprehension and Letter Recognition (ages 7 and younger) subtests. Both the Spelling and Math composites are comprised of one test, respectively Spelling Comprehension and Math Computation. The WRAT-4 was standardized on a sample of 3,007 divided into 19 age groups and matched for age, gender, race/ethnicity, geographic region and educational attainment on the 2007 U.S. census data (Dell, Harrold, & Dell, 2008). Overall, high levels of internal consistency are demonstrated (alpha = 0.92-0.98). Additionally, acceptable content validity has been shown and concurrent validity has been established with the WIAT-II, Woodcock Johnson III, Kaufman Test of Educational Achievement – Brief Form and the WISC-IV (Dell et al., 2008). Clinical utility has been demonstrated in healthy as well as learning disabled children and adults (Dell et al., 2008). The WRAT-4 Word Reading subtest was used to estimate reading achievement.

Motivated Strategies for Learning Questionnaire (MSLQ). The MSLQ (Pintrich, Smith, Garcia, & McKeachie, 1991) is an 81-item self-report measure that is comprised of six subscales measuring student motivation and nine subscales examining learning strategies. Within the learning strategies portion, the Cognitive Strategy Use subscale assesses four types of cognitive strategies for learning (rehearsal, elaboration, organization, and critical thinking). Rehearsal involves repeating information to oneself. Organization includes constructing new information into organized tables, outlines or mental representations. Elaboration involves the summarization of information and critical thinking includes applying new knowledge to novel situations (Crede & Phillips, 2011). Good internal consistency has been demonstrated for this subscale (alpha = 0.83-0.88; Fredricks et al., 2011). Cronbach's alpha for the current study was excellent (alpha = 0.94). Construct validity has been established as the Cognitive Strategy Use subscale is correlated with self-efficacy, interest, and task value (Pintrich, 1999). This measure has been validated in middle school, high school and college populations (Fredricks et al., 2011). The Cognitive Strategy Use subscale was used to measure overall cognitive engagement. Strategy-specific scale scores were used to measure use of rehearsal, elaboration, organization and critical thinking learning strategies. Higher scale scores on this measure indicate increased use of overall engagement or the specific strategy being measured.

Data Analysis Plan

The following data analyses were conducted to test previously listed hypotheses regarding the associations between working memory, executive function, overall and strategy-specific cognitive engagement and academic achievement among pediatric brain tumor survivors. An exploratory analysis was conducted to determine the role of overall and strategy-specific cognitive engagement as a potential mediator between working memory and/or executive functioning and reading achievement.

Descriptive and Preliminary Analyses

(1) Descriptive statistics were computed in order to determine frequencies of population characteristics. The following descriptors were examined: age, age at diagnosis, gender, ethnicity, tumor type and treatment combinations. Frequencies of additional descriptors of the sample included amount of missed school, parental education and family socioeconomic status.

(2) Bivariate correlations using Pearson product-moment correlation coefficients between primary variables were computed to determine preliminary associations. Correlations between the following variables were examined: WASI-II FSIQ-2 score, WISC-IV Digit Span Backwards scale score, BRIEF Metacognitive T-score, MSLQ Cognitive Strategy Use scale score, MLSQ Rehearsal scale score, MSLQ Elaboration scale score, MSLQ Organization scale score, MSLQ Critical Thinking scale score and reading WRAT-4 Word Reading T-score. Additional

bivariate correlations using Pearson product-moment correlation coefficients were computed among secondary variables (amount of missed school, parental education and family socioeconomic status).

Primary Analyses

For all hierarchical multiple regressions, significance was determined by R squared change whereas Cohen's f^2 statistic was used to determine effect size.

(1) To evaluate whether working memory was related to overall and strategy-specific cognitive engagement, when controlling for IQ, hierarchical multiple regression analyses were conducted. For the regression analyses, the WISC-IV Digit Span Backwards scaled score was entered as the predictor and WASI-II FSIQ-2 as a covariate. Separate analyses were conducted in which the MSLQ Cognitive Strategy Use scale score, MSLQ Rehearsal scale score, MSLQ Elaboration scale score, MSLQ Organization scale score, or MSLQ Critical Thinking scale score were entered as the dependent variable. To evaluate whether executive functioning was related to cognitive engagement when controlling for IQ, bivariate correlations and hierarchical multiple regression analyses were run. For the regression analyses, the BRIEF Metacognitive T-score was entered as the predictor and the WASI-II FSIQ-2 as the covariate. Separate analyses were conducted in which the MSLQ Cognitive Strategy Use scale score, MSLQ Rehearsal scale score, MSLQ Elaboration scale score, MSLQ Organization scale score, or MSLQ Critical Thinking scale score were entered as the dependent variable.

(2) To evaluate whether working memory was related to reading achievement when controlling for IQ, a hierarchical multiple regression analysis was conducted. For the regression analysis, WISC-IV Digit Span Backwards scaled score was entered as the predictor variable, WASI-II FSIQ-2 as a covariate and WRAT-4 Word Reading T-score as the dependent variable. To evaluate whether executive functioning was related to reading achievement when controlling for IQ, another hierarchical multiple regression analysis was run. For this regression analysis, the BRIEF Metacognitive T-score was entered as the predictor variable, WASI-II FSIQ-2 as a covariate and WRAT-4 Word Reading T-score as the dependent variable.

Exploratory Analyses

(3) Mediation analyses using bootstrapping methods was conducted to determine whether overall and strategy-specific cognitive engagement mediates the association between neuropsychological functioning and reading achievement (Preacher & Hayes, 2008). Bootstrapping is a nonparametric resampling procedure whereby repeated sampling from the data set occurs in order to estimate confidence intervals for the indirect effect in each resampled data set (Preacher & Hayes, 2008). A nonparametric bootstrapping approach to mediation analysis is advantageous in that it makes no assumptions about the shape of the distribution of the statistic. Therefore, this test can be applied to small samples with more confidence (Preacher & Hayes, 2004). Separate mediational analyses were conducted for working memory and executive functioning. For the mediation analysis, either the WISC-IV Digit Span

Backwards scaled score or the BRIEF Metacognitive T-score was entered as the predictor variable. Separate analyses entered the MSLQ Cognitive Strategy Use scale score, MSLQ Rehearsal scale score, MSLQ Elaboration scale score, MSLQ Organization scale score, and MSLQ Critical Thinking scale score as the mediator variable. The WRAT-4 Word Reading T-score was entered as the dependent variable in all analyses. Significant mediation analyses were determined using 95% confidence intervals; if the range of values between the upper and lower bound of the confidence interval contains zero, the analysis is non-significant.

Power Analyses

Because no previous studies have investigated the association between neurocognitive functioning, cognitive engagement and reading achievement in pediatric brain tumor survivors, there is little foundation for predicting effect size for the planned analyses for this cohort. Therefore, medium effect sizes were predicted as a reasonable middle ground. For the primary analyses, G*Power 3.1.9.2 (Faul, Erdfelder, Lang, & Buchner, 2007) was used to conduct power analyses. According to conventions provided by G*Power to achieve 0.80 power, the recommended sample size for a multiple regression with one predictor variable and one control variable, using an alpha level of 0.05 and a predicted medium effect size, would be 55 participants. The recommended number of participants for each of these analyses exceeds the resources of the current study and therefore suggests an increased risk for Type II error. Given that the MSLQ Cognitive Strategy Use subtest can only be administered in ages 10 and older, this limitation constricted the number of participants tested for this study. A sample size of 27 was achieved and observed power for each for analysis was reported. For analyses that were insufficiently powered, effect sizes were relied upon for interpretation. No power analysis was conducted for the mediation analysis, as nonparametric bootstrapping methods to mediation analyses are robust in small samples (Preacher & Hayes, 2004).

Chapter 3: Results

Descriptive and Preliminary Analyses

Approximately 41% of caregivers reported that their child missed less than two months of school. The remainder of the sample reported school absences that lasted 2-5 months (22.2%), 5-8 months (7.4%) and 8-12 months (25.9%). Approximately one-third of caregivers reported making greater than $125,000 per year (33.3%), while more than two-thirds attended a higher education institution (66.6%). Nearly one-quarter of the caregivers reported completion of a four year higher education institution (22.2%) or graduate/professional school (22.2%). One-way ANOVA's were conducted to determine whether group differences existed for the amount of missed school, caregiver income and caregiver education on all outcomes measures. A significant difference in groups was found between caregiver education level and survivor working memory, $F(7, 17) = 4.27$, $p = 0.007$. Follow-up post-hoc tests were unable to be conducted due to small sample sizes in one or more education level group. Additional information concerning these analyses are detailed in Tables 3-5.

The range of scores for participants in this study are as follows: WASI FSIQ-2 (*M* = 97.73, *SD* = 16.74, range: 68 – 130), BRIEF Metacognitive Index (*M* = 50.15, *SD* = 10.39, range: 36 – 71) WISC-IV Digit Span Backwards (*M* = 8.96, *SD* = 3.13, range: 3 – 15) and WRAT-4 Word Reading (*M* = 101.85, *SD* = 16.89, range: 64 – 145). These ranges indicate performance levels varying from moderately impaired to very superior for the WISC-IV Digit Span Backward and borderline to very superior for the BRIEF Metacognitive Index, as determined by age-based norms. However, mean scores indicate that the sample, on average, performed in the normal range for IQ, executive functioning, working memory and reading achievement. MSLQ results showed variation in both levels of overall cognitive engagement (M = 4.50, SD = 1.34, range: 2.05 – 6.84) and specific strategies used (Rehearsal: M = 5.02, SD = 1.45, range: 2 – 7; Elaboration: M = 4.14, SD = 1.55, range: 1.17 – 6.83; Organization: M = 4.66, SD = 1.75, range: 1 – 7; Critical Thinking: M = 4.41, SD = 1.32, range: 2 – 7). Please refer to Table 6 for more information on descriptive analyses concerning measures.

Bivariate correlations using Pearson product-moment correlation coefficients revealed significant associations between both primary and secondary variables. Participant intelligence (WASI FSIQ-2) was significantly, positively correlated with survivor reading (WRAT-4 Word Reading standard score), $r(25) = 0.72$, $p < 0.001$. There was a significant negative correlation between parent-reported executive functioning (BRIEF Metacognitive Index T-score) and the rehearsal-based (MLSQ Rehearsal scale scores), $r(26) = -0.48$, $p = 0.01$ and organization-based cognitive strategies for learning (MSLQ Organization scale scores), $r(26) = -0.39$, $p = 0.04$. Survivor working memory scale scores demonstrated significant positive correlations with reading achievement (WRAT-4 Word Reading standard score), $r(26) = 0.41$, $p = 0.04$. All MSLQ scales displayed significant positive correlations with one another (all $ps < 0.05$). Please refer to Table 7 for more information regarding correlations among primary and secondary variables.

Primary Analyses

Executive Function. Hierarchical multiple regression analyses revealed that BRIEF Metacognitive Index T-scores significantly predicted MSLQ Rehearsal scale scores while controlling for WASI FSIQ-2, R^2 change = 0.21, b = -0.07, SE_b = 0.03, $t(25)$ = -2.55, p = 0.018. These results yielded a medium effect size, Cohen's f^2 = 0.27. For this model, the assumption of normality of the residuals was violated, however no correction was made, as all independent and dependent variables were normally distributed. Analyses also revealed that BRIEF Metacognitive Index T-scores significantly predicted MSLQ Organization scale scores while controlling for WASI FSIQ-2, R^2 change = 0.16, b = -0.07, SE_b = 0.03, $t(25)$ = -2.09, p = 0.048. These results yielded a medium effect size, f^2 = 0.19. For this model, the assumptions of normality was violated, however no correction was made as all independent and dependent variables were normally distributed. All other hierarchical multiple regression analyses with the BRIEF Metacognitive Index as the predictor variable and the WASI FSIQ-2 as the control variable were non-significant. Please refer to Table 9 for more information on hierarchical multiple regression analyses with the BRIEF Metacognitive Index T-score entered as the predictor variable and the WASI FSIQ-2 as the control variable.

Working Memory. Findings revealed that WISC-IV Digit Span Backward scale scores significantly predicted WRAT-4 Word Reading standard scores while controlling for WASI FSIQ-2, R^2 change = 0.09, b = 2.39, SE_b = 1.17, $t(24)$ = 2.05, p = 0.05. These results yielded a small effect size, f^2 = 0.10. Outliers were determined by calculating the probability of Mahalanobis D^2, a multivariate assessment of each observation's distance from the mean center of all observations. A conservative threshold of $p = 0.001$ was used for the probability of Mahalonobis D^2 for each participant (Hair Jr., Black, Babin, & Anderson, 2010). Also, standard scores were created for each case and those falling outside of 2.5 standard scores or greater were removed. For this model, Mahalobobis D^2 was not violated, however one case was removed because it was 4.19 standard scores greater than the mean (Hair Jr. et al., 2010). For more information regarding hierarchical multiple regression analyses with the WISC Digit Span Backward scale score entered as the predictor variable and the WASI FSIQ-2 as the control variable, please reference Table 8. All other hierarchical multiple regression analyses with the WISC-IV Digit Span Backward as the predictor variable and WASI FSIQ-2 as the control variable were non-significant.

Exploratory Analyses

All mediation analyses revealed non-significant results (all *ps* > 0.05). For information regarding mediation analyses in which the WISC-IV Digit Span Backward scale score was entered as the predictor variable and the WRAT-4 Word Reading standard score as the outcome variable, please refer to Table 10. For information regarding mediation analyses in which the BRIEF Metacognitive Index T-score was entered as the predictor variable and the WRAT-4 Word Reading standard score as the outcome variable, please refer to Table 11.

Chapter 4: Discussion

This investigation sought to determine the association between neurocognitive functioning, cognitive engagement and reading achievement in pediatric brain tumor survivors. Findings show that lower executive function abilities are related to reduced use of rehearsal- and organization-based cognitive strategies for learning. This provides preliminary evidence for the reduced use of both deep and shallow learning strategies in survivors with executive function difficulties. Results did not demonstrate an association between executive functioning and elaboration- and critical thinking-based learning strategies. Furthermore, working memory was not associated with any subscale of cognitive engagement.

Executive Functioning, Cognitive Engagement and Reading Achievement

Multiple hierarchical regression analyses indicated that parent-rated executive functioning predicts the use of survivor-reported rehearsal- and organization-based cognitive learning strategies. This finding is mostly consistent with previous literature, which demonstrated an association between various executive function domains (e.g. motivational drive, planning and organization) and MSLQ Rehearsal and Organization scale scores (Garner, 2009). However, there are some differences from the extant literature in that no association was found between elaboration and executive function. This difference may be attributed to the fact that in the prior study elaboration was significantly predicted by motivational drive and impulse control (Garner, 2009), two sub-categories of executive function not measured by the BRIEF Metacognitive Index (Garner, 2009; Roth, Isquith, & Gioia, 2005).

Lower scores in executive functioning were associated with reduced use of rehearsal-based cognitive strategies for learning. This implies that survivors with lower scores in executive functioning exhibit lower levels of rote memorization as a means for learning new material. The direction of this relationship is contradictory to previous literature in which children and adolescents with TBI demonstrated an increase in rote memorization during learning (Gamino et al., 2009). Furthermore, rehearsal is a fundamental learning strategy that is first to develop and most commonly witnessed during learning in elementary and middle school-aged students (Kintsch, 1990). Given that rehearsal is a more rudimentary strategy that is established and practiced within the age range of the participants in this study, we did not expect a demonstrated relationship between decreased use of rehearsal and increased executive function difficulties. However, our results imply that declines in executive functioning may influence one's ability to engage with course material at a shallow level.

More infrequent use of organization based strategies was also associated with lower executive abilities, indicating that survivors may demonstrate an inability to engage with course material in a meaningful manner when they are exhibiting lower levels of executive functioning. Organization involves one's ability to select meaningful information from presented material and construct connections among the selected information (Pintrich et al., 1991). Utilization of this learning strategy is important in that it allows for mental representations of material to be constructed in such a manner that allows for better understanding of the information, therefore making it easier to retrieve in future instances (Greene et al., 2004). Decreased use of this strategy in relation to lower executive function abilities suggests that pediatric brain tumor survivors may experience difficulty identifying important pieces of information and manipulating that material in a way that promotes meaningful learning (Greene et al., 2004). Organization-based strategy use has been shown to promote higher levels of academic performance, and therefore declines in the use of this learning strategy may be associated with school difficulties in pediatric brain tumor survivors. However, our study showed no relationship between organization strategy use and reading achievement. This finding may be influenced by the choice of reading achievement measure, such that the selection of important information and manipulation of material may not be utilized in word reading tasks.

Contrary to our a priori hypothesis, executive functioning demonstrated no association with reading achievement. The lack of an association between these two constructs may explain the non-significance of all mediation analyses containing the BRIEF Metacognitive Index as the predictor and WRAT-4 Word Reading subscale as the outcome variable. Previous literature shows inconclusive results regarding the association between executive function and reading achievement (Walda, van Weerdenburg, Wijnants, & Bosman, 2014). Most studies examining the association between executive function and reading achievement have compared reading disabled children with typically developing children or other clinical pediatric populations (e.g., ADHD). Mixed results have emerged as to whether those with reading impairments differ in their executive function skills as compared to control groups (Walda et al., 2014). Much of these discrepancies in findings have been attributed to differences in measures of executive function, as each task assesses a different combination of executive function skills. Task-based measures of executive function also involve non-executive abilities that may act as covariates among executive function skills and reading achievement (Booth, Boyle, & Kelly, 2010).

Another potential explanation regarding the lack of an association between executive function and reading achievement is the use of a parent-report measure of executive function rather than a performance-based task. Rater-based instruments, such as the BRIEF, are advantageous in that they can be completed through various methods (e.g. in person, online, via mail), are less time intensive, require little or no training for completion, and demonstrate ecological validity. Furthermore, parent reports are beneficial in that they remove complications due to lack of insight or awareness of the child regarding his or her behaviors (Chaytor, Schmitter-Edgecombe, & Burr, 2006; Howarth et al., 2013). In addition, previous literature conducted with other cognitively impaired pediatric populations has shown that the BRIEF is more sensitive than performance-based measures of executive function but that it also lacks significant associations with such tasks (Howarth et al., 2013). Howarth and colleagues (2013) demonstrated that the BRIEF Working Memory scale has both poor sensitivity and specificity among pediatric brain tumor survivors and moderate correlations with the WISC-IV digit span forward and backward subscales. Further, Howarth and colleagues (2013) found that parents over-reported working memory deficits on the BRIEF as compared to results from both the digit span forward and backward subscales of the WISC-IV. Thus, future research should incorporate a combination of parent-report and performance-based measures of executive function and working memory.

Working Memory, Cognitive Engagement and Reading Achievement

Consistent with a priori hypotheses, working memory demonstrated an association with reading achievement. Often described as a component of executive function, previous literature has demonstrated that working memory is its own entity (McCabe, Roediger III, McDaniel, Balota, & Hambrick, 2010). Also, it has been found to be the strongest predictor of reading achievement among various executive function domains (Engel de Abreu et al., 2014). In agreement with previous literature, correlations in this investigation indicate that as working memory impairments increase, word reading scores decrease (Engel de Abreu et al., 2014). This suggests that working memory may play a role in word reading skills among pediatric brain tumor survivors. Word reading tasks involve letter and word decoding through letter identification and word recognition (Wilkinson & Robertson, 2006). Working memory may play a role in this process by temporarily holding different components of the letter identification and word recognition process while one attempts to combine this information in order to read the word presented.

In contrast to expectations, working memory demonstrated no association with overall or strategy-specific cognitive engagement. Contradictory to previous literature and the SOI Model, which provides a conceptual description of working memory that theoretically relates to various cognitive engagement learning strategies, it may be possible that working memory is separate from much of these skills (Mayer, 1996). Working memory is defined as the act of holding material in order to complete a task or activity (Mayer, 1996; Roth et al., 2005). However, our findings imply that the act of summarizing and organizing this material into coherent mental representations may not accurately represent the purpose of working memory as measured by the WISC-IV Digit Span Backward task. It is possible that this activity does not involve the same degree of material manipulation that the organization scale on the MSLQ assesses. This simple maintenance of material is conceptually similar to rehearsal in that it does not involve any manipulation of incoming information; however, it may be distinctly separate in that it does not entail the attempt to learn or store that information long-term e (Pintrich et al., 1991; Roth et al., 2005).

Elaboration and critical thinking were not related to either executive function or working memory. Following treatment completion, pediatric brain tumor survivors acquire new information at a slower rate than healthy peers, rather than losing what is previously learned (Mulhern, Merchant, et al., 2004). This struggle to attain new information may also indicate a compromised ability to learn to use more complex learning strategies. Fredricks and colleagues (2004) suggest that cognitive engagement builds upon itself as children age and then becomes more solidified as strategy use increases. Although no research has examined the development of cognitive engagement specifically, previous literature demonstrates that individuals begin with rehearsal-based learning strategies in both elementary and middle school (Kintsch, 1990). During middle school, the ability to summarize material develops whereas organization and abstracting meaning from material develops in adolescence and young adulthood (Brown & Day, 1983). Given the targeted age range for this study, children may have not yet developed their ability to elaborate and think critically with new information. Furthermore, it is hypothesized that once cognitive engagement skills are established they develop in the sense that one can apply them to a variety of situations (Fredricks et al., 2004). Given this, it is possible that survivors have a difficult time learning how to apply each strategy among new types of material and assignments. Future longitudinal research should examine cognitive engagement and specific learning strategies to better determine any specific patterns in development of such skills.

Chapter 5: Limitations and Future Directions

This study contains several notable limitations. First, this study collected data at any of the three time points that were pre-determined by the parent study. Given this, survivors' time since diagnosis ranged from less than one month to greater than one year post treatment completion. Data collection from one time point alone would be more ideal in that it would eliminate time since treatment completion as a potential source of variance in outcome measure scores. To examine data collection time point as a potential source of variance, one-way ANOVA analyses were performed examining the data time point as the fixed factor and each outcome measure (WASI FSIQ-2, WISC-IV Digit Span Backward, BRIEF Metacognitive Index, WRAT-4 Word Reading, MSLQ Total, MSLQ Rehearsal, MSLQ Elaboration, MSLQ Organization and MSLQ Critical Thinking) as the dependent variable. All tests were non-significant (all $ps > 0.05$), implying that there is no group differences in data collection time point. For more information regarding these analyses please refer to Table 12.

The lack of uniformity in time since treatment completion is also important, in that most pediatric brain tumor survivors display cognitive impairments between one to two years following completion of tumor-directed treatment (R. W. Butler & Mulhern, 2005). Because this study collected data at baseline through the one year follow-up, it is possible that those whose data was collected at the one year follow-up could potentially display more cognitive deficits than those tested at an earlier time point. Furthermore, the fact that data collection occurred so quickly following treatment completion, it is possible that some survivors may not yet be experiencing the full extent of his or her cognitive decline (R. W. Butler & Mulhern, 2005). For this study, participants' mean scores were in the normal range for measures of executive functioning, working memory and reading achievement. Therefore, it is possible that the sample has adequate executive functioning and may not demonstrate deficits in these domains as time from treatment completion increases. Future research should look to examine these associations starting at later time points. Prospective studies may want to begin their baseline data collection at one-year following treatment completion, since this is typically when pediatric brain tumor survivors begin to exhibit neurocognitive late effects. Longitudinal studies should include follow-up assessments through to the second year following treatment completion (R. W. Butler & Mulhern, 2005)

The choice of measures for reading achievement and cognitive engagement may have influenced findings. First, utilizing the WRAT-4 Word Reading subtest provides a more narrow measure of reading achievement, in that it specifically measures decoding skills (Cirino et al., 2013; Dell et al., 2008). Reading achievement is ideally measured as a combination of three skills: decoding, comprehension and fluency (Cirino et al., 2013). Due to time constraints during the testing battery, it was not feasible to add a set of measures assessing all three components of reading achievement. The WRAT-4 was chosen as the test to be used in that it is consistent with the battery provided by neuropsychologists in the Neuro-Oncology department at CHOP. This allowed for reduced complications in data collection occurring with survivors who received a full neuropsychological assessment within Neuro-Oncology in addition to their participation in this study. Previous literature has identified decoding and comprehension as areas of impairment among pediatric brain tumor survivors greater than six months from treatment completion (Kieffer-Renaux et al., 2000; Reeves et al., 2006). Also, findings from Keiffer-Renaux (2000) and colleagues imply that treatment intensity for whole brain irradiation may not effect decoding skills, but does play a role in comprehension impairments. Given that treatment type and intensity were not controlled for in this study, a measure of decoding was favored during measure selection. The use of a decoding measure was also selected to align with previous literature stating that most individuals who contain reading difficulties demonstrate decoding difficulties (Cirino et al., 2013). However, most students demonstrate difficulties in more than one component of reading achievement, therefore, future research should aim to examine reading achievement using a composite score of all three skills and examine each skill in relation to cognitive engagement, executive functioning, and working memory separately. These three components may be measured through academic achievement batteries such as the WRAT-4 and Woodcock-Johnson III or may utilize separate measures designed to measure each specific component. Furthermore, future research should look to gather information regarding any diagnosed reading-related learning disabilities from caregivers or teachers.

With regards to cognitive engagement, the MSLQ was selected due to limited assessment options measuring this construct and feasibility. The Regional Educational Laboratory Southeast prepared a comprehensive list of assessments used to measure school engagement, and provides extensive information regarding each measure’s content, the setting in which it is administered, the age range it can be used with and the psychometric properties (Fredricks et al., 2011). Through this list, tests were first narrowed to assessments that measured specifically cognitive engagement and that were self-report-based. Teacher and observation-based measures were not chosen due to the time constraints of the study and doubts in the feasibility of reliably obtaining results from such measures. While eight self-report measures were identified as assessments that addressed cognitive engagement, only two had specific subscales measuring cognitive engagement (the Attitudes towards Mathematics exam [ATM] and the MSLQ). Because the ATM specifically examines cognitive engagement in relation to mathematics, this test was ruled out and the MSLQ was chosen, as it addresses all subjects. Future research may want to utilize teacher reports and observational methods in order to avoid subjective responses that often occur with self-report measures (Nezu & Nezu, 2008). Additionally, prospective studies may explore the possibility or using the Reading Engagement Index (REI), in that it is a teacher-based report and specifically examines cognitive engagement in relation to reading tasks.

The MSLQ also provides limitations in data analysis due to the fact that it does not contain clinical cutoffs; while this questionnaire has demonstrated good reliability and validity, there is no norm data available for comparison and no guideline in determining advantageous versus disadvantageous levels of cognitive engagement. Furthermore, to the best of my knowledge, this questionnaire has not been administered to pediatric brain tumor survivors. Future research may want to assess reliability and validity of this measure within this population.

The analyses for this study did not statistically control for the amount of school the survivor missed due to treatment and treatment-related events following diagnosis. While not statistically controlled for, this study did measure this factor and found that many survivors missed less than two months of school (40.7%). To examine amount of missed school as a potential source of variance, one-way ANOVA analyses were performed examining the data time point as the fixed factor and each outcome measure (WASI FSIQ-2, WISC-IV Digit Span Backward, BRIEF Metacogntive Index, WRAT-4 Word Reading, MSLQ Total, MSLQ Rehearsal, MSLQ Elaboration, MSLQ Organization and MSLQ Critical Thinking) as the dependent variable. All tests were non-significant (all *ps* > 0.05), implying that there is no group differences in amount of missed school. For more information regarding these analyses please refer to Table 3.

Future research should further examine the association between amount of missed school due to treatment and consequences related to neuropsychological functioning and cognitive engagement. School absenteeism is problematic in that interrupts one's learning and school engagement. While not studied in pediatric brain tumor survivors, increased school absenteeism has been shown to be related to decreased Math and English letter grades in another chronically ill pediatric population (Krenitsky-Korn, 2011). Further, potential associations between neurocognitive functioning, cognitive engagement and additional educational services received both during (e.g. receiving tutor services while receiving inpatient treatment) and following treatment (i.e. IEP) may be of interest. It may be possible that those who are receiving supplementary educational services are being taught advantageous learning strategies, and therefore exhibiting higher levels of overall and strategy-specific cognitive engagement.

Chapter 6: Clinical Implications

Findings from this study have several clinical implications regarding learning strategies in the pediatric brain tumor population. Survivors who exhibit executive dysfunction following treatment-completion may be at risk for decreased use of an advantageous learning strategy, organization. Interventions may be implemented to promote advantageous learning strategies and suppress the use of rehearsal when this strategy is not conducive to meaningful learning. Potential interventions may address this problem by directly targeting learning strategies or indirectly through helping these students develop compensatory strategies for executive functioning.

School-based interventions targeting learning strategies may incorporate ‘coaches for students’ learning’, or educators who teach about learning processes and strategies through a variety of methods. Despite demonstrated importance for incorporating this into class lecture, it is rare that teachers act on this. Furthermore, class curriculum and training programs for educators fail to include information regarding learning strategies (Hamman, Berthelot, Saia, & Crowley, 2000). Hamman and colleagues (2000) investigated the frequency of coaching of learning strategies in middle school classrooms and its association with rehearsal, elaboration and organization as measured by the MSLQ. Frequently used methods used to coach included describing the cognitive process, suggestion of learning strategies for a particular task or assignment, and providing a rational for using a particular learning strategy. Both organization and elaboration showed high rates of suggested use, whereas rehearsal was discussed minimally. Last, the use of all three learning strategies was significantly related to the frequency of suggested use by the teacher during coaching periods (Hamman et al., 2000). These findings imply that coaching of learning strategies influences the strategies students select and utilize.

Given results from previous literature in combination with our findings, pediatric brain tumor survivors may benefit from exposure to coaching for learning strategies. In particular, the suggestion of a particular learning strategy could aid survivors with executive function deficits in the selection of advantageous learning strategies while demoting the use of rehearsal-based strategies. Teachers providing students with suggestions for learning strategies should be aware of the context in which they are providing such information. First, it is important for teachers to embed the strategy instruction into the context of meaningful work. If the strategy is not taught in a situation that is similar to how students should be using the strategy on assignments or during studying, a dissociation between the strategy and these scenarios may arise (D. L. Butler, 1995). Second, instructors should begin explaining and providing rationale for the strategy at the beginning of the task, while carrying this instruction throughout the activity. This allows students to understand the strategy as a means to achieve a particular goal. A dissociation between the task and strategy may also arise if the strategy is introduced once at the end of the completed activity (D. L. Butler, 1995). Last, conversations regarding strategy use should be engaging, allowing students to reflect on the usefulness and applicability of the strategy being presented (D. L. Butler, 1995).

Interventions targeting executive functioning may also be useful in that we would expect, based on our findings, the use of organization-based strategies to increase as executive function abilities increases. Cognitive rehabilitation programs for individuals with executive dysfunction provide insight into school and home-based clinical implications for our findings. Among children with executive function deficits, the cognitive rehabilitation literature is limited but provides some guidelines for several strategies in promoting executive functioning. To date, one cognitive rehabilitation program has been documented in pediatric cancer survivors, but this program aimed to reduce attention deficits. Findings show modest improvements in attention following program completion, suggesting that cognitive rehabilitation programs may be mildly effective within this population (R. W. Butler & Mulhern, 2005). Cognitive rehabilitation programs among similar populations that target executive function also provide evidence for reduced executive dysfunction following program completion. Direct instruction training administered with elementary-aged students with a history of traumatic brain injury (TBI) was found to improve task performance and generalize to school performance (Limond & Leeke, 2005). This form of training is similar to coaching for learning in that it involves providing direct instruction of strategies for effectively reading a text or passage (Limond & Leeke, 2005).

Other recommended executive function rehabilitation strategies for children with TBI include the use of external aids, expressive writing, rehearsal of reading material out loud, and formation of outlines. External cues are used to target difficulties with planning, organization and initiation (K. Cicerone, Levin, Malec, Stuss, & Whyte, 2006; Shaw, 2014). An external cue such as a sheet or workbook listing various options for effective learning strategies could be placed in a location the student frequently completes assignments (e.g. at home or school). The survivor could be trained to utilize that sheet or workbook prior to completing assignments or studying so that he or she avoids using rote memorization and, instead, implements a more effective strategy for learning. This may also be useful in that it reduces the teacher's responsibility to provide strategy suggestions to the child. Expressive writing is a technique that allows one to outline and sequence thoughts concerning presented information. This technique is conceptually related to elaboration, in that it directs one to produce a summary of the recently learned information. Furthermore, expressive writing promotes organization by encouraging students to write out the mental representation, or framework, of the selected information (Shaw, 2014). Next, rehearsal of reading material out loud involves the student selecting important information and summarizing that material following reading, promoting elaboration. As a follow up to this summarization, the creation of outlines regarding the selected information has students utilize organization by constructing coherent representations of the material both internally and in written form (Shaw, 2014).

Providing parents with the training and tools necessary to implement both coaching for learning and executive function rehabilitation strategies has the potential to provide survivors with greater reinforcement of compensatory strategies provided by school and hospital personnel. First, parents could be educated on the various learning strategies and when teaching each strategy is conducive to meaningful learning. This information would better allow parents to provide their child with suggestions on when to use which learning strategy and why that strategy would be most beneficial. Second, parents could assist their child in creating external cues for promoting the use of advantageous learning strategies. Parents may best understand where an ideal location for such external cues are and can monitor the effectiveness of the external cue in order to make any necessary adjustments for optimal use.

In addition to these suggested interventions, pediatric brain tumor survivors with executive dysfunction may benefit from problem-solving therapy. Problem-solving therapy has been shown to improve executive functioning in child and adolescent TBI and multiple sclerosis patients (Portaccio et al., 2010; Wade et al., 2015). Therefore, the use of problem-solving therapy in pediatric brain tumor survivors may also reduce executive impairments, which could, in turn, increase the use of organization-based learning strategies. Furthermore, problem-solving therapy implemented in pediatric TBI patients resulted in improvements in school functioning, suggesting that this type of intervention may also assist in improving academic achievement (Wade et al., 2015).

Problem-solving is conceptually related to the use of a learning strategy in that it involves: (1) defining the task or assignment-related goal, (2) selecting the most effective learning strategy to use, (3) assessing the resources needed to implement that strategy and (4) evaluating the effectiveness of that strategy in attaining that particular goal (K. D. Cicerone et al., 2011).Teachers may be useful in helping students with the selection process in that they could provide a rational for using a specific strategy so that survivors will understand the types of situations and tasks in which that strategy is most useful and why it is effective then (Hamman et al., 2000). Furthermore, the addition of educating the survivor on problem-solving steps will be beneficial in helping that individual understand what he or she needs before implementing the learning strategy and how to evaluate its effectiveness (D. L. Butler, 1995; K. D. Cicerone et al., 2011).

In conclusion, pediatric brain tumor survivors are at risk for reduced ability to select important information and create coherent mental representations of that material when exhibiting greater executive dysfunction. Interventions targeting learning strategy use and executive functioning may reverse this pattern by increasing survivors' use of organization-based learning strategy. Suggestions for intervention methods can be derived from past research analyzing teacher-based coaching for learning, executive functioning rehabilitation and problem-solving therapy. Future research should focus on examining the developmental trajectory of cognitive engagement to document any longitudinal patterns of learning strategy use. Comparisons regarding cognitive engagement profiles between survivors and healthy peers may promote a better understanding deficits in cognitive engagement within this population. Additionally, prospective studies should also utilize more comprehensive measures for executive functioning, cognitive engagement and reading achievement.

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Appendix

Table 1. Participant demographics

SURVIVOR	N (%)
Gender	
Male	10 (37)
Female	17 (63)
Ethnicity	
Caucasian	21 (77.8)
African-American	5 (18.5)
Asian	--
Hispanic/Latino	1 (3.7)
Other	--
Tumor Type	
Low Grade Glioma	7 (25.9)
Low Grade Astrocytoma	9 (33.3)
Ependymoma	1 (3.7)
Meningioma	1 (3.7)
Germinoma	3 (11.1)
Germ Cell Tumor	1 (3.7)
Medulloblastoma	2 (7.4)
Ganglioglioma	3 (11.1)
Treatment	
Biopsy	18 (66.7)
Resection	11 (40.7)
Chemotherapy	12 (44.4)
Cranial/Craniospinal Radiation	8 (29.6)
Missed School	
Less than 2 months	11 (40.7)
2-5 months	6 (22.2)
5-8 months	2 (7.4)
8-12 months	7 (25.9)

CAREGIVER	N (%)
Gender	
Male	1 (3.7)
Female	26 (96.3)
Ethnicity	
Caucasian	21 (77.8)
African-American	5 (18.5)

Table 1 (continued). Participant demographics

Asian	--
Hispanic/Latino	1 (3.7)
Other	--
Annual Income	
Less than $10,000	2 (7.4)
$10,000 - $19,000	3 (11.1)
$20,000 - $34,000	1 (3.7)
$35,000 - $49,000	1 (3.7)
$50,000 - $74,000	4 (14.8)
$75,000 - $99,000	3 (11.1)
$100,000 - $124,000	2 (7.4)
Greater than $125,0000	9 (33.3)
Highest Educational Level	
Completed 8th Grade	1 (3.7)
Completed High School	5 (18.5)
Attended a 2-year college	2 (7.4)
Completed a 2-year college	2 (7.4)
Attended a 4-year college	--
Completed a 4-year college	6 (22.2)
Attended professional/graduate school	2 (7.4)
Graduated professional/graduate school	6 (22.2)
N/A	1 (3.7)

Participant demographics as reported at baseline

Table 2. Measures and data collection time points

Construct	Measure	Baseline	Six Months	One Year
Characteristics of Child and Caregiver	Demographic Questionnaire	X	X	X
Intelligence	WASI-II Matrix Reasoning and Vocabulary subtests	X		X
Working Memory	WISC-IV Digit Span Backwards subtest	X	X	X
Executive Functioning	BRIEF Metacognitive subscale	X	X	X
Reading Achievement	WRAT-4 Word Reading subtest	X	X	X
Cognitive Engagement	MSLQ Cognitive Strategy Use subscale	X	X	X

Table 3. One-Way ANOVA analyses: Group differences on outcome measures based on amount of missed school.

	df	*SS*	*MS*	*F*	*p*	n^2_p
1. WASI FSIQ-2	25	120.53	40.18	0.14	0.93	0.02
2. WISC-IV Digit Span Backward	26	25.83	8.61	0.83	0.49	0.10
3. BRIEF Metacognitive Index	26	113.78	37.93	0.33	0.81	0.04
4. WRAT-4 Word Reading	26	1225.37	408.46	1.91	0.16	0.21
5. MSLQ Total	26	3.46	1.15	0.60	0.62	0.08
6. MSLQ Rehearsal	26	1.72	0.57	0.24	0.87	0.03
7. MSLQ Elaboration	26	10.55	3.52	1.50	0.24	0.17
8. MSLQ Organization	26	2.00	0.67	0.20	0.90	0.03
9. MSLQ Critical Thinking	26	5.85	1.95	1.10	0.37	0.13

*$p<0.05$

Table 4. One-Way ANOVA analyses: Group differences on outcome measures based on caregiver income.

	df	*SS*	*MS*	*F*	*p*	n^2_p
1. WASI FSIQ-2	25	1341.46	191.64	0.65	0.71	0.22
2. WISC-IV Digit Span Backward	26	81.17	11.60	1.14	0.39	0.32
3. BRIEF Metacognitive Index	26	869.81	124.26	1.26	0.33	0.34
4. WRAT-4 Word Reading	26	232.30	324.53	0.10	1.00	0.04
5. MSLQ Total	26	12.40	1.77	0.92	0.52	0.28
6. MSLQ Rehearsal	26	15.22	2.17	0.97	0.49	0.29
7. MSLQ Elaboration	26	18.95	2.71	1.09	0.41	0.31
8. MSLQ Organization	26	22.82	3.26	1.07	0.42	0.31
9. MSLQ Critical Thinking	26	11.29	1.61	0.82	0.59	0.25

*$p<0.05$

Table 5. One-Way ANOVA analyses: Group differences on outcome measures based on caregiver education.

	df	*SS*	*MS*	*F*	*p*	n^2_p
1. WASI FSIQ-2	25	1933.60	276.23	1.07	0.43	0.32
2. WISC-IV Digit Span Backward	26	161.24	23.14	4.27	0.007*	0.64
3. BRIEF Metacognitive Index	26	690.27	98.61	0.91	0.53	0.27
4. WRAT-4 Word Reading	26	1456.69	208.10	0.82	0.58	0.25
5. MSLQ Total	26	8.70	1.24	0.58	0.76	0.19
6. MSLQ Rehearsal	26	7.04	1.01	0.37	0.91	0.13
7. MSLQ Elaboration	26	12.80	1.83	0.64	0.72	0.21
8. MSLQ Organization	26	18.02	3.33	0.77	0.62	0.24
9. MSLQ Critical Thinking	26	9.17	1.31	0.63	0.73	0.21

*$p<0.05$

Table 6. Descriptive analyses for study measures

	M	*SD*	Min.	Max.	Range
1. WASI FSIQ-2	97.73	16.74	68.00	130.00	62.00
2. WISC-IV Digit Span Backward	8.96	3.13	3.00	15.00	12.00
3. BRIEF Metacognitive Index	50.15	10.39	36.00	71.00	35.00
4. WRAT-4 Word Reading	101.85	16.89	64.00	145.00	81.00
5. MSLQ Total	4.50	1.34	2.05	6.84	4.79
6. MSLQ Rehearsal	5.02	1.45	2.00	7.00	5.00
7. MSLQ Elaboration	4.14	1.55	1.17	6.83	5.67
8. MSLQ Organization	4.66	1.75	1.00	7.00	6.00
9. MSLQ Critical Thinking	4.41	1.32	2.00	7.00	5.00

Table 7. Bivariate correlations

	1	2	3	4	5	6	7	8	9
1. WASI FSIQ-2									
2. WISC-IV Digit Span Backwards	0.72***								
3. BRIEF Metacognitive Index	-0.31	-0.38							
4. WRAT-4 Word Reading	0.51**	0.41**	-0.12						
5. MSLQ Total	0.09	0.05	-0.34	0.09					
6. MSLQ Rehearsal	0.18	.14	-0.48*	-0.07	0.85**				
7. MSLQ Elaboration	0.11	0.01	-0.28	0.19	0.95**	0.73**			
8. MSLQ Organization	0.07	0.19	-0.39*	-0.10	0.89**	0.85**	0.77**		
9. MSLQ Critical Thinking	-0.07	-0.15	-0.08	0.26	0.81**	0.48**	0.80**	0.54**	

*p<0.05
**p<0.01
***p<0.001

Table 8. Hierarchical multiple regressions: Models with WISC-IV Digit Span Backward as the predictor variable

	R^2 Change	*b*	*SE_b*	*t*	*Sig.*	*f^2*	*Achieved Power*
1. MSLQ Total							
WASI FSIQ-2	0.01	0.01	0.02	0.20	0.85	0.01	0.08
WISC-IV Digit Span Backward	0.01	0.02	0.13	0.12	0.91	0.01	0.08
2. MSLQ Rehearsal							
WASI FSIQ-2	0.03	0.01	0.03	0.49	0.63	0.03	0.14
WISC-IV Digit Span Backward	0.001	0.02	0.14	0.17	0.86	0.001	0.05
3. MSLQ Elaboration							
WASI FSIQ-2	0.01	0.02	0.03	0.57	0.58	0.01	0.08
WISC-IV Digit Span Backward	0.003	-0.04	0.15	-0.26	0.80	0.003	0.06
4. MSLQ Organization							
WASI FSIQ-2	0.01	-0.02	0.03	-0.55	0.59	0.01	0.08
WISC-IV Digit Span Backward	0.05	0.18	0.17	1.08	0.29	0.05	0.19
5. MSLQ Critical Thinking							
WASI FSIQ-2	0.01	0.003	0.02	0.12	0.90	0.01	0.08
WISC-IV Digit Span Backward	0.01	-0.06	0.12	-0.50	0.63	0.01	0.08
6. WRAT-4 Word Reading							
WASI FSIQ-2	0.41	0.30	0.21	1.46	0.16	0.70	0.98
WISC-IV Digit Span Backward	0.09	2.39	1.17	2.05	0.05*	0.10	0.34

*p<0.05

Table 9. Hierarchical multiple regressions: Models with BRIEF Metacognitive Index as the predictor variable

	R^2 Change	*b*	*SE_b*	*t*	*Sig.*	*f^2*	*Achieved Power*
1. MSLQ Total							
WASI FSIQ-2	0.01	-0.003	0.02	-0.16	0.88	0.01	0.08
BRIEF Metacognitive Index	0.13	-0.05	0.03	-1.83	0.08	0.14	0.45
2. MSLQ Rehearsal							
WASI FSIQ-2	0.03	0.003	0.02	0.17	0.87	0.03	0.14
BRIEF Metacognitive Index	0.21	-0.07	0.03	-2.55	0.02*	0.27	0.72
3. MSLQ Elaboration							
WASI FSIQ-2	0.01	0.002	0.02	0.10	0.93	0.01	0.08
BRIEF Metacognitive Index	0.08	-0.04	0.03	-1.45	0.16	0.08	0.28
4. MSLQ Organization							
WASI FSIQ-2	0.01	-0.01	0.02	-0.31	0.76	0.01	0.08
BRIEF Metacognitive Index	0.16	-0.07	0.03	-2.09	0.048*	0.19	0.57
5. MSLQ Critical Thinking							
WASI FSIQ-2	0.01	-0.01	0.02	-0.52	0.61	0.01	0.08
BRIEF Metacognitive Index	0.02	-0.02	0.03	-0.61	0.55	0.02	0.11
6. WRAT-4 Word Reading							
WASI FSIQ-2	0.38	0.49	0.14	3.42	0.003*	0.61	0.97
BRIEF Metacognitive Index	0.002	-0.06	0.23	-0.25	0.81	0.002	0.06

*$p<0.05$

Table 10. Mediation analyses: WISC-IV Digit Span Backward as the predictor variable and WRAT-4 Word Reading as the outcome variable

Mediator	*Effect*	*Boot SE*	*95% CI*	k^2
1. MSLQ Total	0.02	0.19	-0.31 – 0.45	0.004
2. MSLQ Rehearsal	-0.10	0.34	-1.17 – 0.29	0.02
3. MSLQ Elaboration	0.01	0.23	-0.39 – 0.54	0.003
4. MSLQ Organization	-0.19	0.42	-1.68 – 0.22	0.04
5. MSLQ Critical Thinking	-0.27	0.44	-1.71 – 0.20	0.07

*$p<0.05$

Table 11. Mediation analyses: BRIEF Metacognitive Index as the predictor variable and WRAT-4 Word Reading as the outcome variable

Mediator	*Effect*	*Boot SE*	*95% CI*	k^2
1. MSLQ Total	-0.03	0.12	-0.38 – 0.14	0.02
2. MSLQ Rehearsal	0.13	0.21	-0.21 – 0.64	0.07
3. MSLQ Elaboration	-0.08	0.12	-0.49 – 0.05	0.05
4. MSLQ Organization	0.11	0.18	-0.13 – 0.62	0.06
5. MSLQ Critical Thinking	-0.03	0.10	-0.29 – 0.09	0.02

*p<0.05

Table 12. One-Way ANOVA analyses: Group differences on outcome measures based on data collection time point.

	df	*SS*	*MS*	*F*	*p*	n^2_p
1. WASI FSIQ-2	25	533.53	266.76	0.95	0.40	0.08
2. WISC-IV Digit Span Backward	26	10.87	5.43	0.53	0.59	0.04
3. BRIEF Metacognitive Index	26	361.28	180.64	1.77	0.19	0.13
4. WRAT-4 Word Reading	26	511.48	255.74	0.89	0.42	0.07
5. MSLQ Total	26	4.15	2.08	1.18	0.32	0.09
6. MSLQ Rehearsal	26	7.84	3.92	2.01	0.16	0.16
7. MSLQ Elaboration	26	3.53	1.76	0.72	0.50	0.06
8. MSLQ Organization	26	6.19	3.10	1.02	0.38	0.08
9. MSLQ Critical Thinking	26	2.14	1.07	0.59	0.56	0.05

*p<0.05

The Motivated Strategies for Learning Questionnaire (MSLQ; Pintrich et al., 1991)

The following questions ask about your learning strategies and study skills for this class. Again, there are no right or wrong answers. Answer the questions about how you study in this class as accurately as possible. Use the same scale to answer the remaining questions. If you think the statement is very true of you, circle 7; if a statement is not at all true of you, circle 1. If the statement is more or less true of you, find the number between 1 and 7 that best describes you.

1	2	3	4	5	6	7
Not at all true of me						*Very true of me*

1. When I study the readings for this course, I outline the material to help me organize my thoughts.

2. I often find myself questioning things I hear or read in this course to decide if I find them convincing.

3. When I study for this class, I practice saying the material to myself over and over.

4. When I study for this course, I go through the readings and my class notes and try to find the most important ideas.

5. When studying for this course, I read my class notes and the course readings over and over again.

6. When a theory, interpretation, or conclusion is presented in class or in the readings, I try to decide if there is good supporting evidence.

7. I make simple charts, diagrams, or tables to help me organize course material.

8. I treat the course material as a starting point and try to develop my own ideas about it.

9. When I study for this class, I pull together information from different sources, such as lectures, readings, and discussions.

10. I memorize key words to remind me of important concepts in this class.

11. I try to relate ideas in this subject to those in other courses whenever possible.

12. When I study for this course, I go over my class notes and make an outline of important concepts.

13. When reading for this class, I try to relate the material to what I already know.

14. I try to play around with ideas of my own related to what I am learning in this course.

15. When I study for this course, I write brief summaries of the main ideas from the readings and my class notes.

16. I try to understand the material in this class by making connections between the readings and the concepts from the lectures. Review of the MSLQ.

17. Whenever I read or hear an assertion or conclusion in this class, I think about possible alternatives.

18. I make lists of important items for this course and memorize the lists.

19. I try to apply ideas from course readings in other class activities such as lecture and discussion.