5-3-2007

Cognitive Predictors of Adaptive Functioning in Children with Tumors of the Cerebellar and Third Ventricle Regions

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COGNITIVE PREDICTORS OF ADAPTIVE FUNCTIONING IN CHILDREN WITH TUMORS OF THE CEREBELLAR AND THIRD VENTRICLE REGIONS

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ABSTRACT

As pediatric brain tumor survival rates increase, research has begun to further explore the influence of brain tumors and their treatment on functioning. The current study explored the ability of attention, learning, and memory abilities as measured by the Rey Auditory Verbal Learning Test and receptive language abilities as measured by the Peabody Picture Vocabulary Test to predict adaptive functioning on the Vineland Adaptive Behavior Scales. Children with tumors of the cerebellar region were hypothesized to display relative impairments in attention, whereas children with tumors of the third ventricle region were hypothesized to display relative impairments in learning and memory. The cognitive measures also were hypothesized to be differentially predictive of adaptive functioning performance. No significant differences were found between the groups on cognitive performance, but attention was the best predictor of adaptive functioning in the cerebellar group, whereas receptive verbal knowledge was the best predictor for the third ventricle group.

INDEX WORDS: Adaptive Behavior, Cerebellum, Brain Neoplasm, Pediatric, Attention, Language

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A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of

Master of Arts

in the College of Arts and Sciences

Georgia State University

2007

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May 2007

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Brain tumors represent approximately 22% of cancer cases seen in children (Linet et al., 1999); and, with advances in the field of medicine, brain tumor survival rates are increasing. Consequently, research exploring the impact of brain tumors, as well as the resulting medical treatment, on the developing brain is growing. This research has begun to clarify how brain functioning is affected by a tumor and its treatment, as well as how the young brain develops. This knowledge can then be used to identify areas at risk of developmental delay within this population, and it also can be used more specifically to help clinicians in clarifying distinct areas in need of support in individual patients.

In children treated for brain tumors, level of functioning has historically been assessed using measures of intelligence (IQ). These measures clarify how the presence, and treatment, of a brain tumor influence cognitive functioning. Intellectual functioning is not, however, able to predict fully how an individual is able to relate to, and interact in, the world. Measures of adaptive functioning serve this purpose; providing a way to assess how well people are able to function both personally and socially in their environment. These measures assess the level of independence an individual has obtained across many areas of life relative to same age peers. Research in this area and with this population has been largely neglected in spite of the belief that children with brain tumors may display adaptive functioning deficits even in the presence of average IQ (Packer et al., 1987). Furthermore, increasing adaptive functioning in this population may be a pressing concern for families who hope to see their children lead independent lives one day, and it may even be seen to supersede issues surrounding any cognitive deficits.

The Vineland Adaptive Behavior Scales (VABS) is a widely used measure of adaptive functioning (Sparrow et al., 1984). It divides the construct into three domains for school age children, each measuring age-appropriate behavior. The Communication domain assesses receptive, expressive, and written communication skills. The Daily Living Skills

Domain includes measures of personal, domestic, and community abilities. The Socialization Domain assesses interpersonal, play/leisure, and coping skills.

Attempts to improve adaptive functioning may be most successful when the construct is broken down even further into more basic skills such as attention, learning, and memory abilities. Performance in these areas may influence adaptive functioning, however, the relative importance of these cognitive skills may vary across domains. If basic cognitive skills were shown to relate significantly to adaptive functioning performance, then interventions could be aimed at improving these skills, with the intention of also improving adaptive functioning abilities. Studying patients who have impairments in these basic skill areas and exploring how they relate to adaptive functioning performance would help to clarify the nature of this relationship and assist clinicians in further refining treatment protocols.

Relationship between Intellectual and Adaptive Functioning

Intellectual and adaptive functioning have, at times, been assumed to measure the same construct. Studies have not, however, succeeded in finding a consistent relationship between these measures either within the same neurological population, or across populations (Liss et al., 2001; Carpentieri & Morgan, 1996). Adaptive functioning has most commonly been explored in people with mental retardation, especially in children with autism. This is primarily because impairment in adaptive functioning is one of the core deficits required for a diagnosis of mental retardation. In children with autism, global measures of cognitive development have been shown to be positively related to, though not fully able to explain, adaptive functioning (Carpentieri & Morgan, 1996; Schatz & Hamdan-Allen, 1995). There is some evidence to suggest that in children with autism, this relationship may vary according to level of intellectual functioning; with adaptive functioning being more strongly related to intelligence at lower levels of functioning (Liss et al., 2001). This also was shown in children with no formal diagnosis whose Performance IQ was below 80 (Liss et al., 2001). At lower levels of functioning, IQ may act as a rate-limiting factor in the development of adaptive functioning skills. Thus, at lower levels of functioning in this population, IQ and adaptive behavior may both measure similar, more basic skills, such as the ability to understand and master simple tasks. Liss et al. (2001) also showed that tests of language and verbal memory were better predictors of adaptive behavior than IQ in high-functioning children with autism and children with a developmental language disorder. These results suggest that global measures of cognitive functioning may not always be the most sensitive predictors of adaptive functioning.

In children with autism, increases in IQ have been associated with less of an increase in certain adaptive functioning skills than in children with mental retardation (Schatz and Hamdan-Allen, 1995). This serves to highlight the different relationships between the levels of IQ and adaptive functioning across populations. Furthermore, Carpentieri and Morgan (1996) found that the correlation between VABS domain scores and SB-IV area scores was higher for a group of children with autism than a group of nonautistic children with comparable IQ composite scores. The children with autism displayed consistently high correlations between SB-IV area scores and all of the VABS domain scores, whereas the children with mental retardation only displayed high correlations between the SB-IV area scores and the VABS Communication domain. Thus, past research suggests that there does not appear to be a consistent relationship between IQ and adaptive functioning at different levels of intellectual functioning nor across different neurological populations.

Few studies have looked at the relationship between IQ and adaptive functioning in children treated for brain tumors. In one such study, patients with lower IQ scores showed a significantly greater impairment in adaptive functioning than those with higher IQ scores (Poggi, et. al., 2005). Furthermore, children treated for brain tumors were shown to be impaired across all adaptive functioning domains regardless of their IQ score, with the greatest impairment being in the Socialization Domain. Another study by Papazoglou et al. (2006) highlighted the ability of measures of language and reasoning to predict adaptive functioning performance three to five years later in a pediatric brain tumor sample. Across all three domains and the Adaptive Behavior Composite, this study showed the predictive utility of the Comprehension and Quantitative subtests of the SB-IV. These findings underscore the relationship between receptive and expressive language abilities, as well as logical and sequential reasoning abilities with adaptive skills in children with brain tumors.

Harrison et al. (1996) used factor analysis to examine the relationship between scores on the Kaufman Assessment Battery for Children and the VABS, and found that adaptive functioning and intelligence are separate, but related constructs. This finding is corroborated by examination of the correlations between VABS scores and Kaufman Assessment Battery for Children Global Scale Standard Scores within a normally developing population which were shown to range from .08 to .52 (Sparrow et al., 1984). Whereas measures of intelligence strive to assess an individual's best performance, the goal of measures of adaptive functioning is to assess an individual's typical level of functioning (McCarver & Campell, 1987). This is an important distinction: measures of adaptive functioning do not seek to assess behaviors that an individual is merely capable of, but rather their typical behavior. Furthermore, measures of intelligence focus on thought processes, while adaptive behavior scales primarily assess behavior. Adaptive behavior is situationally defined; behavior that is adaptive in one setting is not necessarily so in another setting.

Relationship between Adaptive Functioning and Specific Cognitive Skills

Intellectual functioning has not been shown to display a clear and consistent relationship to adaptive functioning. Adaptive functioning is a complex construct and it has proven difficult to improve these skills directly. If, however, it were possible to break this construct down, then intervention could focus on improving those foundational abilities in order to improve adaptive functioning. The relationship between adaptive functioning and more specific cognitive abilities such as attention, memory, learning, and receptive verbal knowledge has been explored to a lesser extent in neurological populations, but might serve to clarify some of the abilities necessary for successful adaptive functioning in a pediatric brain tumor population. These abilities are important means by which knowledge is acquired, stored, and utilized and, therefore, are critical cognitive skills, especially in school-age children. Furthermore, these cognitive abilities are not completely explained by intellectual performance. Several studies have shown that poor attention and memory performance can occur in children treated for a brain tumor with otherwise preserved intelligence (Dennis et al., 1998; King et al., 2004; Micklewright et al., 2006). These cognitive skills do not represent unitary constructs, and can be broken down into different facets. This study will explore the roles of attention supraspan, verbal learning, verbal memory, and receptive verbal knowledge in predicting adaptive functioning performance.

Attention refers to the ability to consistently focus on the task at hand. It is one of the most pervasive features of cognition; influencing the efficiency of many other cognitive processes. Trial 1 of the Rey Auditory Verbal Learning Test (RAVLT) is a supraspan measure with a large attentional component. Supraspan refers to exposure to more stimuli than the immediate attention span can hold. This overload condition is believed to be especially sensitive to deficits in attention. Attention is likely to be of importance in successful performance across all adaptive functioning domains, but may be particularly important for the Communication and Socialization domains. The ability to attend to what someone else is saying to you and be able to respond in a coherent and relevant way, to write a paper for school, to relate and respond to others, and to be a friend all require the ability to focus attention (Lezak, 2004).

Learning refers to the ability to process information quickly and efficiently for the purpose of acquiring knowledge (Lezak, 2004). The sum of Trials 1-5 of the RAVLT measures the total number of words a participant is able to remember over all five trials. Learning ability may be of foremost importance across the Socialization and Daily Living Skills domains which assess how well children have learned to take care of themselves in terms of hygiene, safety, and chores, as well as how well they can interact with others in socially appropriate ways.

Memory includes elements of attention, working memory, encoding, consolidation, storage, and retrieval. Memory impairments can isolate patients from emotionally meaningful contact with others as well as interfere with the retention of new information (Andrewes, 2004). Memory performance is likely to be of the greatest importance across the Socialization and Daily Living Skills domains because in order to interact with people appropriately, remembering the rules of social interaction, as well as pertinent information about your companion, are essential. Furthermore, one must be able to remember to bathe regularly, look both ways before crossing the road, and take cookies out of the oven 10 minutes after you put them in. An inability to remember to do these things is likely to lead to a fairly dependent life.

Receptive verbal knowledge, as measured by the PPVT, assesses vocabulary level. It also has an attentional component because the participant must both attend to the stimulus word for each trial and then examine four line drawings to determine which one matches the word (Dunn & Dunn, 1997). Within a typically developing sample, correlations between the VABS and PPVT-R were shown to range from .12 on the Daily Living Skills domain to .37 on the Communication domain (Sparrow et al., 1984). Within our sample, this measure is likely to be of particular importance for the Communication domain which assesses language comprehension, verbal interaction, and speech, reading, and writing skills.

Unique patterns of the importance for attention, learning, memory, and receptive verbal knowledge abilities may exist for each of the different adaptive functioning domains, and these patterns might also vary according to brain tumor location. For example, within the pediatric brain tumor population, children with tumors in different locations might have similar adaptive functioning profiles, however, they may have very different cognitive ability levels, or patterns of impairment, contributing to their similar functional outcomes. This would advocate the use of different interventions for each group targeting specific cognitive areas. No prior research could be found which explored the nature of the relationship between cognitive skills and adaptive functioning in a pediatric brain tumor population for the purpose of fine-tuning intervention strategies. With children increasingly surviving brain tumors it is important that the focus of research be wide, including not only how to lengthen the lives of these children, but also how to improve the quality of their lives. Measures of adaptive functioning provide a means by which the level of daily functioning can be assessed, and further research into this construct could complement the standard interventions and increase independence as well as quality of life.

The specific adaptive functioning skills being assessed are likely to influence which cognitive variables are the greatest correlates. Language tests, for example, are likely to be most predictive of scores on the Communication Domain (Liss et al., 2001). It is important, however, to move beyond simply validating measures, to look at more basic cognitive skills, such as attention, learning, and memory. It is more challenging to predict the specific nature of the relationship between scores on tasks that assess these more foundational cognitive abilities, which are likely to be of importance for a variety of adaptive functioning skills.

The relationship between adaptive functioning and specific cognitive skills may also differ across populations or levels of functioning. For example, measures of memory were related to Daily Living Skills domain scores in high-functioning, but not low-functioning, children with autism (Liss et al., 2001). In high-functioning children with autism, the California Verbal Learning Test (CVLT) long delay recall, a measure of verbal memory, has been shown to be most predictive of Socialization scores, whereas the Peabody Picture Vocabulary Test (PPVT), a measure of receptive verbal knowledge, was most predictive of Communication scores. This same pattern was not found in low-functioning children with autism, instead Quantitative Reasoning Area scores from the SB-IV were shown to be the best, and the only, significant predictor of adaptive functioning across all domains (Liss et al., 2001).

Tumors of the third ventricle have been associated with impairments in learning and memory, while cerebellar tumors have been associated with impairments in attention (King et al., 2004, Micklewright et al., 2006). These studies have shown that children with tumors of the third ventricle performed significantly worse on list learning and delayed list recall compared to children with tumors of the cerebellum, while children with cerebellar tumors were comparatively more impaired on a measure of attention span. This study seeks to explore the nature of the relationship between attention, learning, memory, as well as receptive verbal knowledge and adaptive functioning performance in a pediatric brain tumor sample.

Unique Opportunity of Studying a Pediatric Brain Tumor Population

The relationship between adaptive functioning and general cognitive ability in children has been shown to vary according to the population studied. This could be the result of children from different neurological populations not acquiring skills, both cognitive and adaptive, either at all, or not in the same sequence or same rate as typically developing children. Research on adaptive functioning in the pediatric brain tumor population has been largely neglected. Studying adaptive functioning in this population, however, allows for a unique opportunity to explore how adaptive functioning is affected in developing children who experience a neurological insult, but whose brains were likely developing typically prior to the tumor and its treatment.

Brain tumors can have a direct effect on neurocognitive status by way of their location in the brain. Tumors can damage both the surrounding neuronal structure and they can also disrupt neuronal pathways, potentially affecting brain functioning in a variety of ways. Childhood cancer survivors are at heightened risk for reduced cognitive and behavioral functioning and this risk has been shown to increase over time (Fletcher & Copeland, 1988; Gamis & Nesbit, 1991, Carlson-Green et al., 1995). Given the specialized nature of many areas of the brain, the specific impact may depend to some degree on the tumor's location in the brain. This study seeks to explore the impact of tumors of the cerebellar and third ventricle areas. Cerebellar and brain stem tumors account for half of all brain tumors in children (Heideman et al., 1993). It is, therefore, of particular importance to understand the effects of tumors in this area of the brain. Tumors in this area have been associated with impairments in attention, whereas tumors of the third ventricle are in close proximity to important pathways and structures for learning and memory. These abilities are all likely to be important for successful adaptive functioning. In addition to tumor prevalence and the specific deficits typically associated with these tumor locations, they were chosen because research has shown that they are associated with different, and non over-lapping, profiles of cognitive impairment. Therefore, using children with tumors in these areas allows us the opportunity to explore how differences in these specific abilities may influence adaptive functioning performance.

Cerebellar Region

The cerebellum is known to have a role in the learning and production of accurate, coordinated movement. Recently, however, studies have suggested an expanded role for the cerebellum, which includes involvement in higher order cognitive functions particularly executive and attentional processes (Fiez, 2001; Desmond, 2001; Schmahman & Sherman, 1998; Klein et al., 1995). The cerebellum is comprised of three nuclei the fastigial, interpositus, and dentate. It is made up of more neurons than the whole of the cerebral cortex and receives 85% of all fibers leaving the cerebral cortex (Glickstein, 1992).

White matter pathways connect the cerebellum with all major areas of the central nervous system including the cerebral cortex, basal ganglia, limbic system, diencephalon, brainstem and spinal cord. The extensiveness of these connections suggests that the cerebellum may play a role in integrating, and perhaps modulating, information from a variety of neural areas. There is evolutionary support for an interaction between the cerebellum and frontal cortices: over the course of evolution, growth of the dentate paralleled expansion of the frontal cortex (Leiner et al., 1993). The existence of such a reciprocal relationship also has been substantiated by research at the neural level. Using retrograde transneural transport, Middleton and Strick (1994) have shown that some of the cerebellum's output is directed to contralateral parts of the prefrontal cortex (PFC) which, in turn, are known to innervate the cerebellum (Schmahmann & Pandya, 1997). This led Schmahmann and Pandya to postulate the existence of closed loops between the PFC and the cerebellum which are distinct from, but run parallel to, the loops serving motor areas. There are also loops linking the cerebellum with posterior parietal (Schmahmann & Pandya, 1989), superior temporal, (Schmahmann & Pandya, 1991), and limbic cortices (Snider & Maiti, 1976).

The existence of such loops allows us to consider a more meaningful role for the cerebellum in cognition. Furthermore, the presence of these loops would suggest that damage to the cerebellum, which interrupts a loop, would produce deficits resembling those produced by the cortical areas subserved by that loop. Indeed, this is evidenced by clinical cases. For example, children with cerebellar/posterior fossa tumors appear to display neuropsychological profiles suggestive of cortical lesions (Scott et al., 2001).

Cerebellar tumors may have particular bearing on attentional skills because of the proximity of the ascending reticular activating system, which, along with other subcortical and cortical areas, modulates attention and arousal. Indeed, lesions of the cerebellum/posterior fossa are commonly associated with deficits in attentional as well as executive processes (Gottwald, et al., 2004; Riva, et al., 1991). Allen and Buxton (1997) found evidence for cerebellar involvement in visual attention in the absence of any motor movement or planning. Functional MRI analyses indicated that the attention task activated one neuroanatomic region of the cerebellum while a motor performance task activated a different region. Courchesne et al. (1994) have postulated that the cerebellum may play a role in the coordination of attention and arousal systems. Thus damage to the cerebellum might result in the alteration of activity in the cerebello-thalamo-cortical loops, and, consequently, the cortical areas that subserve attention (Brodmann areas 6 and 8) (Fabbro, 2000).

Schmahmann and Sherman's landmark 1998 study describing Cerebellar Cognitive Affective Syndrome provided clinical evidence for the cerebellum's role in executive functioning, which refers to the ability to control cognitive operations to attain specific goals. They examined 20 adults with diseases confined to the cerebellum and found a general lowering of intellectual functions marked by impairments in executive functions, spatial cognition, linguistic difficulties, and personality changes.

Children treated for cerebellar/posterior fossa tumors also exhibit deficits in attention. Steinlin et al. (2003) demonstrated impairments in selective attention, processing speed, and divided attention in children with posterior fossa tumors treated only with surgical resection, thereby removing the potentially confounding effects of radiation and chemotherapy treatment. A deficit also was found in executive functioning with a trend towards a significant impairment in phasic alertness. Levisohn et al. (2000) also found deficits in the areas of executive functioning and attention, providing support for the presence of Cerebellar

Cognitive Affective Disorder in children. No significant impairments were found in learning or memory abilities. Similarly, King et al. (2004) noted that children with cerebellar tumors had significantly lower digit span performance, but better learning and memory performance relative to children treated for third ventricle tumors.

Some studies of cognitive functioning after tumor treatment have found more widespread deficits. For example, Riva and Giorgi (2000) observed deficits in auditory sequential memory, language processing, and spatial and visual sequential memory. This study did not, however, control for medical variables such as hydrocephalus or the presence of seizure medication, which have been shown to affect cognitive functioning.

Studies of children and adults with cerebellar/posterior fossa lesions consistently suggest a role for this area in attentional processing. Patients with cerebellar tumors have not been shown to consistently display learning and memory deficits, rather these abilities appear to remain intact. This study seeks to confirm the existence of impairments in attention relative to the third ventricle group, as well as to explore how cognitive performance relates to adaptive functioning in children with cerebellar tumors.

Third Ventricle Region

Unlike the cerebellum, the third ventricle region has been shown to play a role in learning and memory processes. The third ventricle region houses several important neuroanatomical structures and pathways necessary for these processes, including the hypothalamic nuclei, thalamus, fornix, and basal forebrain. Pathology in the third ventricle region of the brain can result in impairments in memory, including amnesia. Memory disturbances have been noted following insult to this region in both adult (Bauer, et al., 1993) and pediatric patients (King et al., 2004) treated for tumors. Verbal learning abilities have also been shown to be impaired in children with tumors of the third ventricle relative to children with cerebellar tumors and in the absence of impairments in attention (King et al., 2004; Micklewright et al., 2006).

In a unique series of studies, Dennis and colleagues (1991a, 1991b, 1992) explored the relationship between brain tumor location and working memory deficits using multiple regression analyses to explore the brain tumor locations most predictive of memory deficits. Forty-six children with brain tumors in 13 regions were administered three memory tests assessing recognition, content, and sequential memory. Recognition memory was impaired in children with tumors of the diencephalon, more specifically in the anterior thalamus, medial-midline thalamus, and pineal gland. Sequential memory deficits were associated with damage to the limbic system and hypothalamic-pituitary axis (Dennis et al., 1991). These studies highlight the role of the third ventricle region in learning and memory processes.

The thalamus plays a critical role in cortical arousal. Studies of patients with thalamic damage have suggested an important role for the thalamus in memory and executive functioning (Van der Werf et al., 2003). Patients with Wernicke-Korsakoff syndrome have confirmed the importance of the third ventricle area in memory. These patients have damage to diencephalic structures including the thalamus, which is believed to play an important role in amnesia. Anterograde amnesia in these patients has been shown to be associated with third ventricle enlargement as well as atrophy of the nuclei in the midline of the thalamus (Visser et al., 1999). Lesions to the thalamus also may interrupt projections to cortical regions.

The fornix, a white matter pathway, is important for memory processes. It is the primary efferent pathway between the hippocampus and diencephalon and is believed to play an especially important role in episodic memory. Aggleton et al. (2000) found that bilateral interruption of the fornix was the only consistent neuroanatomical predictor of poor memory performance in adult patients who had colloid cysts removed from the third ventricle area.

The basal forebrain is important for declarative memory. Damasio (1985) has documented amnesia in patients following basal forebrain lesions. None of the five patients in this study had damage to the brain regions typically associated with amnesia (medial temporal lobes and dorsomedial thalamus), however their recall of previously presented information was impaired. Patients were assessed with the RAVLT, and showed an impaired rate of learning, but recognition memory abilities were within normal limits. Damasio concluded that in these patients, amnesia resulted from basal forebrain lesions, which disrupt connections between medial temporal regions and the hippocampal formation proper, amygdala, and parahippocampal gyrus. Studies of children and adults with lesions in the third ventricle area suggest an important role for this area in learning and memory. This study seeks to confirm the presence of impairments in these abilities relative to the cerebellar tumor group and to explain the relationship between cognitive performance and adaptive functioning in children with tumors of the third ventricle region.

Potentially Confounding Variables

In addition to possible impairments associated with brain tumor location, other variables may impact adaptive functioning in children with brain tumors. These variables may moderate or mediate the relationship between tumor location and adaptive functioning thereby acting as possible confounds. These variables include secondary effects of the tumor, namely resulting medical conditions and treatment effects. Potentially confounding variables will be assessed for their impact on adaptive functioning and for their unequal representation across the two groups. This is done in order to prevent these variables from obscuring the true relationship between tumor location and adaptive functioning.

The relationship between adaptive functioning performance and treatment related variables has been explored by few studies (Poggi et al., 2005, Carlson-Green et al., 1995) and these have tested only a limited number of these variables. Poggi et al. (2005) did not find a significant relationship between sex, age at diagnosis, tumor type, or tumor location and Vineland domain scores, but both Poggi et al. (2005) and Carlson-Green et al. (1995) found evidence for a relationship, though not always a significant one, between time since diagnosis and adaptive functioning performance. Beebe et al. (2005) found that children with cerebellar astrocytomas were at increased risk of adaptive impairment, which was not consistently associated with medical complications. Many studies, however, have explored the influence of these potential confounds on intellectual functioning in great depth, and determined that many of them have deleterious effects on cognitive functioning (e.g. Ris & Noll, 1994; Moore et al., 1992; Ellenberg et al., 1987). In sum, there is sparse research on the influence of treatment factors on adaptive functioning. There is, however, substantial research on the impact of these variables on intellectual functioning, and there has been shown to be a strong correlation between IQ and adaptive functioning in children with brain tumors ($r=.60$, $p<.001$; Poggi et al., 2005). Therefore, variables that have frequently been found to influence intellectual functioning also will be assessed as potential confounds in this study in order to determine whether they are unequally represented across groups and are associated with adaptive functioning.

In order to prevent any variables from obscuring the true nature of the relationship between tumor location and adaptive functioning, the following variables will be examined for their relationship with adaptive functioning and unequal representation across tumor groups. These variables include time since diagnosis, age at diagnosis, treatment type (surgery, whole brain or focal radiation, chemotherapy, combination treatment), seizure medication, and the presence of hydrocephalus.

Time since Diagnosis.

Time since diagnosis and evaluation has been shown to be negatively associated with Adaptive Behavior Composite scores (Carlson-Green et. al., 1995). Poggi et al. (2005), however, examined this relationship by domain, and found a significant relationship only with the Socialization Domain. Less time since diagnosis also has been shown to correlate with higher focused and selective attention scores (Dennis et al., 1998).

Less time post-diagnosis has been shown to be associated with higher intellectual functioning (Carlson-Green et al., 1995). Not taking this variable into account could lead to an over-estimation of the effects of other variables such as age at diagnosis (Ris & Noll, 1989). The amount of time that has elapsed between time of diagnosis and evaluation has been shown to be negatively correlated with performance on cognitive tasks, and deficits may become more pronounced as cognitive demands increase with age or as the long-term effects of treatment become apparent. The relationship between time since diagnosis and cognitive functioning is believed to result from damage disrupting both skills in the midst of acquisition and the ability to develop more complex skills in the future (Gil, 2003; Ellenberg et al., 1987). This relationship may also vary according to the location of the brain tumor. A study measuring IQ over a four year interval in children with tumors of the third and fourth ventricles or hemispheric tumors showed a different pattern of decline and recovery according to tumor location (Ellenberg et al., 1987). Children with tumors of the third and fourth ventricles displayed an increase in IQ from diagnosis to four months post-diagnosis. The third ventricle group then experienced a decline in IQ from four months to one year, and then an increase in IQ from one to four years. The fourth ventricle group, on the other hand, experienced a decline in IQ during the one to four year interval. This study highlights the variability in cognitive decline and improvement and the importance of including time since diagnosis as a variable in neuropsychological research.

Age at Diagnosis.

When examining the effects of brain tumors on children, it is critical to remember that these tumors affect the developing brain. The effects of a tumor, therefore, are likely to vary depending on the brain's developmental stage. Age at diagnosis has been shown to be a significant predictor of intellectual outcome, with younger children typically experiencing more adverse outcomes (Taylor & Alden, 1997; Ellenberg et al., 1987). Similarly, children who were older at time of diagnosis appear to have better intellectual functioning (Fletcher & Copeland, 1988; Gamis & Nesbit, 1991). The possibility that, tumors may disrupt brain functioning during critical times for the development of specific abilities must also be considered. For example, Steinlin et al. (2003) found that children diagnosed with a brain tumor between the ages of 5 and 10 years had more pronounced vocabulary difficulties. The potential for age-dependent differences in outcome underscores the necessity of comparing the mean age of diagnosis for the two tumor groups and examining the potential for a relationship with adaptive functioning.

Treatment.

Treatments for brain tumors are known to affect cognitive outcome and may also affect adaptive functioning. Some research suggests that the type(s) of treatment a child receives is better able to predict long term outcome than tumor location (Ris & Noll, 1994). Further, the use of fewer treatment types has been shown to be associated with higher intellectual functioning (Carlson-Green et al., 1995). The potential influence of surgery, whole brain and focal radiation, and chemotherapy will be examined.

Radiation.

Children receiving radiation therapy without chemotherapy were found to have significantly lower psychosocial, emotional, and social functioning than those receiving other treatments (Bhat et al., 2005). Radiation also has been shown to correlate with poor performance on attention and memory tasks (Dennis et al, 1998; Moore et al., 1992). Whole brain radiation consistently has been shown to negatively impact intellectual abilities as well. Ellenberg et al. (1987) showed that whole brain radiation was associated with cognitive decline, and that this association was even more significant in children younger than seven years. This decline has been shown to be associated with damage to brain structures as a result of treatment (Fletcher & Copeland, 1988). Crossen et al. (1994) have shown that 25-30% of patients undergoing radiation treatment develop radiation associated encephalopathy. The time course and possible transience of the effects of radiation are not fully understood.

Focal radiation is believed to have less of a global impact on functioning. In their review, Ris and Noll (1994) concluded that there were no clear neurobehavioral deficits resulting from focal radiation, but that the potential for damage to surrounding neuronal tissue does exist. The proportion of participants treated with whole brain and/or focal radiation is not expected to differ between the two groups. Neither whole brain, focal radiation, the amount of radiation received, nor the type of radiation have been shown to differ significantly across these two tumor groups (King et al., 2004; Micklewright et al., 2006).

Chemotherapy.

Ellenberg et al. (1987) found that chemotherapy had no clear bearing on intellectual functioning. Other studies have shown that treatment with chemotherapy can cause neurobehavioral impairments in many areas including processing speed, memory, and executive functions (Anderson-Hanley et al., 2002). Chemotherapy has also been shown to be related to poor attention and social withdrawal (Holmquist & Scott, 2002). Treatment with chemotherapy has not been shown to occur at different frequencies across these two tumor locations (King et al., 2004; Micklewright et al., 2006).

Surgery.

Surgical resection of tumors is an invasive technique that disturbs brain circuitry and may damage the brain tissue surrounding the tumor. Carpentieri et al. (2003) found evidence for neuropsychological morbidity, including in the area of verbal memory, in children with brain tumors treated with surgical resection. Additionally, language, sustained attention and executive deficits have been noted following neurosurgery (Aarsen et al., 2004). The use of neurosurgery has been shown to be significantly greater in children with cerebellar tumors as compared to children with tumors of the third ventricle (Micklewright et al., 2006).

Seizure Medication.

Seizures may result from the tumor itself or from the effects of medical treatment. Seizures are associated with high frequency discharge of impulses by a group of neurons in the brain. The site and spread of the abnormal activity affects the type and severity of the symptoms experienced. Seizure medication typically works by reducing the electrical excitability of cell membranes and enhancing GABA-mediated synaptic inhibition. The deleterious effects of both seizures and seizure medication on cognitive abilities have been well documented (Farwell et al., 1990; Khan et al., 2003) and there is the potential for them to also influence adaptive functioning. King et al. (2004) found that the number of children with tumors of the third ventricle who were on seizure medication was significantly greater than the number of children with cerebellar tumors. However, in an independent study using many of the participants included in this study, Micklewright et al. (2006) did not find a significant difference in the number of participants on seizure medication between the two tumor groups.

Hydrocephalus.

Hydrocephalus occurs when the ventricles become enlarged as a result of a distal obstruction. This enlargement places pressure on, and compresses, the surrounding brain matter and blood vessels. Hydrocephalus can cause cognitive changes including memory problems, impaired attention, and executive dysfunction (Hannay et al., 2004). Ellenberg et al. (1987), however, found that adequately treated hydrocephalus had no bearing on intellectual functioning. Studies have not shown a difference in the incidence of hydrocephalus across these two tumor locations (King et al., 2004; Micklewright et al., 2006).

Neurological Predictors Scale.

To assess the possible cumulative effects of treatment, total scores on the Neurological Predictors Scale created by Micklewright et al. (2006) were used. To determine the total score (range 0-11), four domain scores in the areas of tumor and treatment associated conditions, perioperative events, type of radiation treatment, and chemotherapy are summed. Unlike the scale is was modeled after, the Neurological Severity Score (Ater et al.,1996), this scale does not include a rating for pre-diagnosis symptoms and post-operative events owing to the variability found in participant and health care provider reports of these symptoms and events.

In order for any of the above variables to be declared confounds, they must be shown to occur at differing frequencies between the two tumor groups, and also must be shown to be significantly related to adaptive functioning performance. If both of these conditions are not met, then the variable is not a confound. If a variable is found to be a confound, it will be entered as a covariate in each analysis. It is predicted that all of the variables above will occur at equal levels across the two tumor groups, and, therefore, will not be confounds.

Aims of this study

This study seeks to explore the relationship between attention, learning, and memory as measured by the RAVLT, as well as receptive verbal knowledge as measured by the PPVT-R and adaptive functioning in a brain tumor population. Understanding the nature of this relationship is important not only to increase our knowledge of the way tumor location and treatment, cognitive functioning, and adaptive functioning relate to each other, but also to increase our understanding of how developing brains are affected by a neurological insult and its treatment. Greater insight into these areas can then be used to further refine treatment protocols as well as neuropsychological and behavioral interventions.

The general aim of this study is to explore and compare the relationship between cognitive skills and adaptive functioning in children treated for cerebellar tumors and those treated for tumors of the third ventricle. Attention, learning, memory, and receptive verbal knowledge abilities are the particular focus of this study because of their important roles in knowledge acquisition. The cerebellar tumor group was chosen for inclusion because of the prevalence of tumors in this area in children and because cerebellar tumors have been shown to be related to impairments in attention, but not learning and memory. The third ventricle group was included because tumors in this area have been associated with impairments in learning and memory, but not consistently with attention. This study explored the differences in performance in these areas, as well as receptive verbal knowledge, across the two tumor locations and also assessed how relative differences in cognitive performance between the two groups relate to adaptive functioning performance. The non-overlapping pattern of cognitive deficits in these populations make them ideal comparison groups. Furthermore, by using two brain tumor groups the levels of potentially confounding variables are likely to be at comparable levels across groups.

The specific aim of this study was to examine how deficits in specific cognitive skills correlate with adaptive functioning domains and how these correlations may vary by tumor location. Additionally, this study sought to identify which measures of cognitive functioning were best able to differentiate between the two tumor groups.

Hypotheses

1. *Tumor Location as a Predictor of Cognitive Performance*

It is hypothesized that tumor location can be used to predict cognitive performance. These hypotheses will illustrate where there are significant differences in cognitive performance between the groups.

H1.a: It is hypothesized that the cerebellar group will be impaired on a measure of attention supraspan, Trial 1 of List A of the RAVLT, relative to the third ventricle group.

H1.b: It is hypothesized that the third ventricle group will be impaired on measures of learning and memory, Trials 1-5 of List A and the Long Delay Free Recall Trial of the RAVLT, as compared to the cerebellar group.

H1.c It is hypothesized that both tumor groups will perform in the average range on a measure of receptive verbal knowledge.

2. *Cognitive Predictors of Overall Adaptive Behavior by Location*

It is broadly hypothesized that attention, learning, and memory as measured by the RAVLT and receptive verbal knowledge as measured by the PPVT-R will be differentially predictive of VABS Adaptive Behavior Composite scores across the two tumor groups. This is predicted because these cognitive abilities are believed to influence the pattern of adaptive functioning performance. A different relationship between cognitive abilities and adaptive functioning may be the result of these abilities being of unequal importance across the different domains or to the construct of adaptive functioning, in general, and could be further influenced by the different ways that cognitive impairments might exert their influence, namely by increasing or decreasing the correlation with adaptive functioning.

H2: It is hypothesized that there will be significant differences between the two tumor groups on how well cognitive measures can predict overall adaptive functioning.

3. *Cognitive Predictors of Adaptive Behavior Domains by Location*

It is further hypothesized that these cognitive measures will be differentially predictive of the VABS domain scores: Communication, Socialization, and Daily Living Skills. Little research has been done exploring how these cognitive abilities relate to adaptive functioning domains, therefore, it is challenging to predict which abilities will be significant predictors of the different domains, however, past research was used as a foundation for the following hypotheses:

H3.a: For the cerebellar group, the predicted relative impairment in attention is likely to affect performance across domains, but is predicted to significantly relate to performance on the Communication and Socialization Domains.

H3.b: For the third ventricle group, the predicted relative impairments in learning and memory are hypothesized to be significant predictors of their performance on the Daily Living Skills and Socialization domains.

H3.c For both tumor groups, receptive verbal knowledge is hypothesized to be a significant predictor of performance on the Communication domain.

4. *Cognitive Variables as Mediators of the Relationship between Treatment and Adaptive Functioning*

Little is known about the relationship between select treatment and medical variables (time since diagnosis, age at diagnosis, chemotherapy, radiation, and hydrocephalus), cognitive variables, and adaptive functioning. In order to learn more about how these variables may relate to each other, the possible existence of a mediational relationship will be explored.

H4: It is hypothesized that some treatment variables may act as significant predictors of adaptive functioning and that this relationship may be mediated by cognitive performance.

Method

Participants

Participants for this study were part of a longitudinal research project investigating the effects of primary brain tumors and their treatment on aspects of child and family functioning. They were recruited from the pediatric medical centers in the metropolitan Atlanta area where they were seeking treatment. At specific intervals (diagnosis, if possible, six months following diagnosis, and then yearly) intellectual, academic, neuropsychological, and psychological testing was conducted. Inclusion in this retrospective study was contingent on participants having tumors in either the cerebellar/posterior fossa or third ventricle regions with no tumor pathology encroaching on the tumor area of the comparison group. Inclusion also was contingent on being administered the Rey Auditory Verbal Learning Test, Peabody Picture Vocabulary Task-Revised and the Vineland Adaptive Behavior Scales within seven years of diagnosis (*M* = 2.42 years, *SD* = 2.20, *Range*: .11 to 6.97). No participants in this sample had a preexisting diagnosis of Attention Deficit Hyperactivity Disorder or a learning disability.

Thirty-six children with cerebellar or third ventricle tumors met the inclusion criteria. Seventeen participants had cerebellar tumors, and had a mean age of 6.08 years at time of tumor diagnosis (*SD* = 4.33years) and a mean age at time of evaluation of 8.58 (*SD* = 3.73). This group was comprised of 7 males and 10 females (see Table 1). Nineteen participants had tumors of the third ventricle with a mean age of 9.93 years (*SD* = 4.25 years) at diagnosis and a mean age of 12.06 years (*SD* = 3.59) at time of evaluation. This group was comprised of 12 males and 7 females. Of the seventeen cerebellar participants, 16 were Caucasian and 1 was African American. Of the nineteen third ventricle participants, 16 were Caucasian and 3 were African American. Mean SB-IV IQ Composite scores were in the average range for both the cerebellar (*M* = 98.71, *SD* = 12.42, *Range:* 78-117) and third ventricle groups (*M* = 101.32,

Table 1

Demographic Variables According to Tumor Location Group

	Tumor Location	
Demographic Variables	Cerebellar	Third Ventricle Region
Number of participants	17	19
Mean age at diagnosis	6.08*	9.93*
Mean age at evaluation	8.58*	12.00*
Male to female ratio	7:10	12:7
Caucasian to African American ratio	16:1	16:3
Mean estimate of SES	3.33	3.05
Mean SB-IV Composite Score	98.71	101.32

* $p < .05$
** $p < .01$
*** $p < .001$

SD = 16.21, *Range:* 70-123) The mean socioeconomic status (SES), as assessed by the Hollingshead Two-Factor Index of Social Position (Hollingshead, 1957) which uses parental occupation and educational level to estimate SES, fell near the midpoint of the scale for both the cerebellar ($M = 3.33$, $SD = 1.14$) and third ventricle groups ($M = 3.05$, $SD = 1.35$). Age at diagnosis (t (34) = -.27, p =.01) and evaluation (t (34) = -2.40, p <.05) were shown to be the only significant differences between the two groups.

Neuroanatomical Verification

Neuroanatomical verification of tumor location was completed at the time of entry into the study by radiologists and neurologists in the metro Atlanta area. Information pertaining to tumor location was collected from participant's medical records. See Table 2 for tumor histology.

Neuropsychological Measures

The Vineland Adaptive Behavior Scales (VABS) is comprised of three domains, which provide an estimate of personal and social sufficiency: Communication, Daily Living Skills, and Socialization. Children can be assessed by the VABS from birth onwards. The VABS survey form was administered to each child's primary caretaker. For each of the three school-age domains, age-adjusted standard scores with a mean of 100 ($SD = 15$) can be calculated. An Adaptive Behavior Composite (standard score) takes into account scores on all the domains. The Communication domain is comprised of questions assessing the subdomains of receptive, expressive, and written communication. The Daily Living Skills domain includes the subdomains of personal, domestic, and community abilities. The Socialization domain measures the subdomains of interpersonal, play/leisure, and coping skills. Within each domain, questions assess increasingly complex developmental milestones until a ceiling is established. The measure thus assesses age-appropriate adaptive functioning.

Table 2

Tumor Type by Tumor Location Group

	Number of Participants
Cerebellar	
Medulloblastoma	10
Astrocytoma	6
Ganglioglioma	1
Third Ventricle Region	
Craniopharyngioma	6
Astrocytoma	5
Germ cell	2
Glioma	2
Ependymoma	1
Ganglioglioma	1
Germinoma	1
Pineoblastoma	1

Review of the psychometric properties of this measure show that the VABS has good reliability and validity. Test-retest reliability was examined using the caregivers of children from 0 months to 18 years and 11 months of age, who were re-tested after a two to four week interval (Sparrow et al., 1984). Correlations were shown to be good across all age ranges with the majority in the high eighties and low nineties. Interrater reliability was assessed using the caregivers of 160 children age 6 months through 18 years and 11 months who were interviewed twice over a period of one to fourteen days by two different interviewers. The correlations between raters were high for the raw scores of all three domains ranging from .96 for Socialization to .99 for Communication (Sparrow et al., 1984). Construct validity refers to the degree to which the underlying construct said to be measured by the scale is actually measured. As expected, adaptive functioning scores have been shown to progressively increase with age. Factor analysis of the domain scores at different age ranges all produced one significant factor, which accounted for 55.4% to 69.8% of the variance. This demonstrates the validity of the Adaptive Behavior Composite. Factor analysis also confirmed the organization of the subdomains into their respective domains (Sparrow et al., 1984).

The Rey Auditory Verbal Learning Test (RAVLT) is a measure of attention span, verbal learning, memory, interference, and recognition memory. In this task, the participant learns a list of 15 orally presented common nouns over five learning trials. Immediately following each learning trial is a free recall test. Following the administration of all five trials, an interference list, list B, of 15 different common nouns is presented and is also followed by a free recall test. A free recall of list A is then obtained (i.e., short delay free recall). Following a delay of 20 minutes, the examinee is then asked to recall list A (long delay free recall). Finally, the examiner reads a list of 50 words which includes all fifteen words form list A as well as thirty-five distracter (recognition) words and the examinee indicates which words were part of list A.

This study included the following variables: Trial 1, sum of words recalled across Trials 1-5, and long delay free recall trial. Trial 1 provides a measure of verbal attention span. The sum of Trials 1-5 assesses learning ability, while the long delay free recall trial provides a measure of memory abilities.

The RAVLT only reports norms by age group, and there is no individual set of norms with an adequate sample size that covers the entire age range of this task. This study used the different norms compiled by Micklewright et al. (2006) to calculate z-scores. Normative data from a large sample of Midwestern children was used for children aged 5 or 6 (Bishop et al., 1990). Data from a sample of children and adolescents was used to calculate z-scores for the following age ranges: 7-12 and 14-15 (Forrester & Geffen, 1991). Data from a sample of adolescents was used for participants aged 17 (Geffen et al., 1990). Additionally, Munson's (1987) data on a sample of adolescents was used to calculate Z-scores for participants ages 13 and 16.

The RAVLT has been shown to have good reliability and validity. Delaney et al. (1992) found correlations between parallel forms of the RAVLT (forms A and C) ranged from .61 and .86 across trials 1-5, and .51 to .72 for the recall trials. The RAVLT has been shown to display good convergent validity with the California Verbal Learning Test (CVLT), which shares the same design (Stallings et al., 1995). Raw scores were found to be significantly correlated for all trials and ranged from .49 for trial 1 to .83 for the sum of Trials 1-5.

The Peabody Picture Vocabulary Test-Revised (PPVT-R; Dunn & Dunn, 1981) is an achievement test that measures the extent of vocabulary acquisition in children 2.5 years of age and older as well as adults. It also serves as a screening test of intellectual ability, assessing verbal ability in people for whom English has been the primary language of instruction. The PPVT-R consists of 175 stimulus words of increasing difficulty. Each item, or plate, consists of four line drawings and the participant is instructed to point to the picture that goes with a word.

The PPVT-R has adequate validity and reliability. It has correlations with other vocabulary tests ranging from .40 to .76. Those measures which had lower correlations with the PPVT-R also are dependent on word retrieval or expressive language skills, those measures with higher correlations require the examinee to point or use single word responses. The PPVT-R also correlates more strongly with Wechsler Verbal IQ scores than Performance IQ scores (Dunn & Dunn, 1996). Bracken & Murray (1984) showed that the PPVT-R had a stability coefficient of .84 over an 11 month period in a nonclinical sample of 1st through 5th graders and similar reliability rates were found using alternate forms of the PPVT-R (McCallum & Bracken, 1981).

Procedure

Participants for this study were part of a longitudinal research project at Georgia State University investigating the effects of primary brain tumors and their treatment on child and family functioning. At specific intervals (diagnosis, if possible, six months following diagnosis, and then yearly) evaluations were conducted with the child treated for a brain tumor and the legal guardian. Evaluations included measures of cognitive and adaptive functioning. Consent and assent was obtained from all participants at the time of each evaluation. The RAVLT, PPVT, and SB-IV were administered to participants during their involvement in the study. The VABS survey form was administered to each child's primary caregiver. The first evaluation when the measures were administered was used for each participant. This was done to ensure that participants are unlikely to have had prior exposure to any of the neuropsychological measures administered, thereby avoiding the potentially confounding effects of practice.

Results

In order to test the hypotheses of this study, scores from the VABS, RAVLT, and PPVT-R were used. Z-scores were computed for all measures, however, given the lack of cohesive norms for the RAVLT, parallel analyses also were run using age-covaried raw scores for all measures. A correlation analysis was conducted with those measures chosen for inclusion in the model to confirm the absence of multicollinearity. Multicollinearity occurs when variables are highly intercorrelated and results in partial regression coefficients being distorted or deflated. The correlation between any two variables did not exceed .8, thereby confirming the absence of multicollinearity.

Power Analyses

The data used for this study is archival, however, a power analysis was conducted in order to determine the sample size that would be needed to detect the effects of interest. This analysis will also be used in order to make inferences about whether the effect sizes associated with any non-significant findings, might become statistically significant with the appropriate sample size. Few studies have explored the relationship of cognitive abilities and adaptive functioning, particularly in a pediatric brain tumor population, and no studies were found that explored the possibility of differences in this relationship according to brain tumor location. Prior data on which to estimate the effect sizes could not always be found using the same, or even similar measures, therefore the values were considered rough estimates of the ideal sample size needed to determine if a significant effect exists. The BWPower computer program was used (Bakeman & McArthur, 1999) to conduct all power analyses. All estimates of the amount of variance accounted for were converted into R^2 values. For all analyses, power as set to .80 and alpha was set to .05.

Our hypotheses explore the ability of cognitive measures to predict adaptive functioning performance. Based on prior research, the following variables were hypothesized to be the most likely confounds, and thus would be entered at step1: time since diagnosis (R^2=.05; Poggi et al., 2005), combination treatment as indicated by the number of different treatment modalities (R^2=.07; Carlson-Green et al., 1995), and mean amount of radiation (R^2=.06; King et al., 2004). The three variables are hypothesized to share some variance, so their mean of .06 was used as an estimate of the amount of variance for which confounds might account.

Preliminary analysis of a sample of children with various brain tumor locations 0 to 5 years post-diagnosis, explored the ability of the RAVLT and PPVT-R to predict adaptive functioning performance. The Communication and Socialization domains showed small effect size for these measures (R^2=.07; R^2=.05), whereas the Daily Living domain showed a medium effect size (R^2=.16). It is expected that our effect sizes will be larger than these owing to a more stringent study design. This study seeks to compare two brain tumor location, will control for any confounding treatment related variables, and examines the relationship between cognitive abilities and adaptive functioning performance across a small time period of 1 to 3 years post-diagnosis. Indeed other studies have found medium to large effect sizes using different measures, e.g. the composite score from the Scales of Independent Behavior-Revised and a measure of focused attention, (R^2=.29; Price et al., 2003) and using different populations, e.g. a high functioning autism population (correlations between the RAVLT, CVLT and VABS ranging from R^2=.14 to R^2=.51; Liss et al., 2001).

With four independent variables, in order to detect a medium effect size, our ideal sample would be 84, and in order to detect a large effect size, our ideal sample size would be 38. At our sample size of 37, if we predict that any confounds entered at step 1 will yield an

R^2=.06, and that our measures of cognitive abilities will yield an R^2=.24 (medium-large effect) then the power to detect our desired effect is .80.

Potential Confound Analysis

For the purposes of this study, a confound was defined as a variable that is both significantly differentially presented across the tumor groups and is significantly related to adaptive functioning. Scores on the Adaptive Behavior Composite were used as the dependent variable to assess whether potential confounds were related to adaptive functioning. Confound analyses were conducted both with Composite z-scores as well as age covaried raw scores. Any variable determined to be a confound will be entered as a covariate in each analysis. It is important to test for potential confounds and to control for them if there are significant differences across groups. This is done to ensure that any significant correlations are due to the independent variables and not due to the influence of confounded variables.

Prior to running the analyses, the distribution of continuous variables was examined for normality. Time since the completion of radiation, total dose of focal radiation, and the time since completion of chemotherapy were found to be positively skewed. For these variables, Spearman's two-tailed correlations were used to correct for the non-normal distribution. For normally distributed continuous variables, two-tailed Pearson's correlations were conducted. For dichotomous variables, Fisher exact tests or Chi-square analyses were used. The independent samples test used was determined by two factors: if the total number of participants treated with the potential confound is greater than 20, and the frequency of every cell is greater than 5, a Chi-Square analysis was performed. If either of these conditions was not met, a Fisher Exact test was performed. Following the determination of whether any potential confounds are differentially represented across the two tumor locations, the relationship between these potential confounds and performance on the Adaptive Behavior

Composite was assessed. This was done by conducting correlation analyses with each confound and the participant's Composite score (z-scores as well as age-covaried raw scores). See Table 3 for an overview of the significance levels of the potential confounds.

Time since Diagnosis.

The amount of time that had elapsed since diagnosis was not significantly different between the two tumor locations (t (34) = .82, p = .42). The mean number of days since diagnosis was 999.76 days (SD = 815.22) for the cerebellar group and 777.78 days (SD = 798.55) for the third ventricle group. A Spearman correlation coefficient was calculated on the non-normally distributed time since diagnosis and the Adaptive Behavior Composite using z-scores (r = -.22, p = .20) and age-covaried raw scores (r = .002, p = .99) and was found to be non-significant. Time since diagnosis was not considered to be a confound in the current sample.

Age at Diagnosis.

The age at which participants in the two groups were diagnosed was significantly different (t (34) = -.27, p = .01). The mean age at diagnosis was 6.08 years (SD = 4.33) for the cerebellar group and 9.93 years (SD = 4.25) for the third ventricle group. A Pearson correlation coefficient was calculated to determine whether there was a significant relationship between age at diagnosis and the Adaptive Behavior Composite. There was a trend towards significance using z-scores (r = .31, p = .06) but not using age-covaried raw scores (r = -.02, p = .92). Although age at diagnosis does not meet the criteria for being a confound, given the significant difference between the two groups and the trend towards a significant relationship to the Composite z-scores, analyses were conducted both with age at diagnosis entered as a covariate as well as without it being treated as a confound. See Figures 1 and 2 for the relationship between age at diagnosis and adaptive functioning z-scores by tumor group. In contrast to Figure 1 showing the cerebellar group, Figure 2 illustrates a

Table 3

Significance Levels of Variables Examined as Potential Confounds

Variable	Tumor Location	Adaptive Functioning	
		Age-Covaried Raw Score	Z-score
Time since Diagnosis	*p* = .42	*p* = .99	*p* = .20
Age at Diagnosis	*p* = .01**	*p* = .92	*p* = .06
Radiation Treatment	*p* = .34	*p* = .29	*p* = .77
Amount of Radiation	*p* = .02*	*p* = .15	*p* = .33
Time since Radiation	*p* = .17	*p* = .80	*p* = .17
Whole-brain Radiation	*p* = .52	*p* = .56	*p* = .63
Cranio-spinal Radiation	*p* = .70	*p* = .81	*p* = .72
Focal Radiation	*p* = .02*	*p* = 1.00	*p* = .58
Amount of Focal Radiation	*p* = .07	*p* = .24	*p* = .89
Spinal Radiation	*p* = .11	*p* = .42	*p* = .61
Chemotherapy	*p* = 1.0	*p* = .69	*p* = .61
Time since Chemotherapy	*p* = .12	*p* = .80	*p* = .58
Neurosurgery	*p* = .00***	*p* = .67	*p* = .24
Hydrocephalus	*p* = .41	*p* = .25	*p* = .11
Seizure Medication	*p* = .70	*p* = .53	*p* = .81
NPS Total Score	*p* = .65	*p* = .24	*p* = .06

* $p < .05$
** $p < .01$
*** $p < .001$

Figure 1

The Relationship between Age at Tumor Diagnosis and Z-scores on the VABS Composite for the Cerebellar Tumor Group

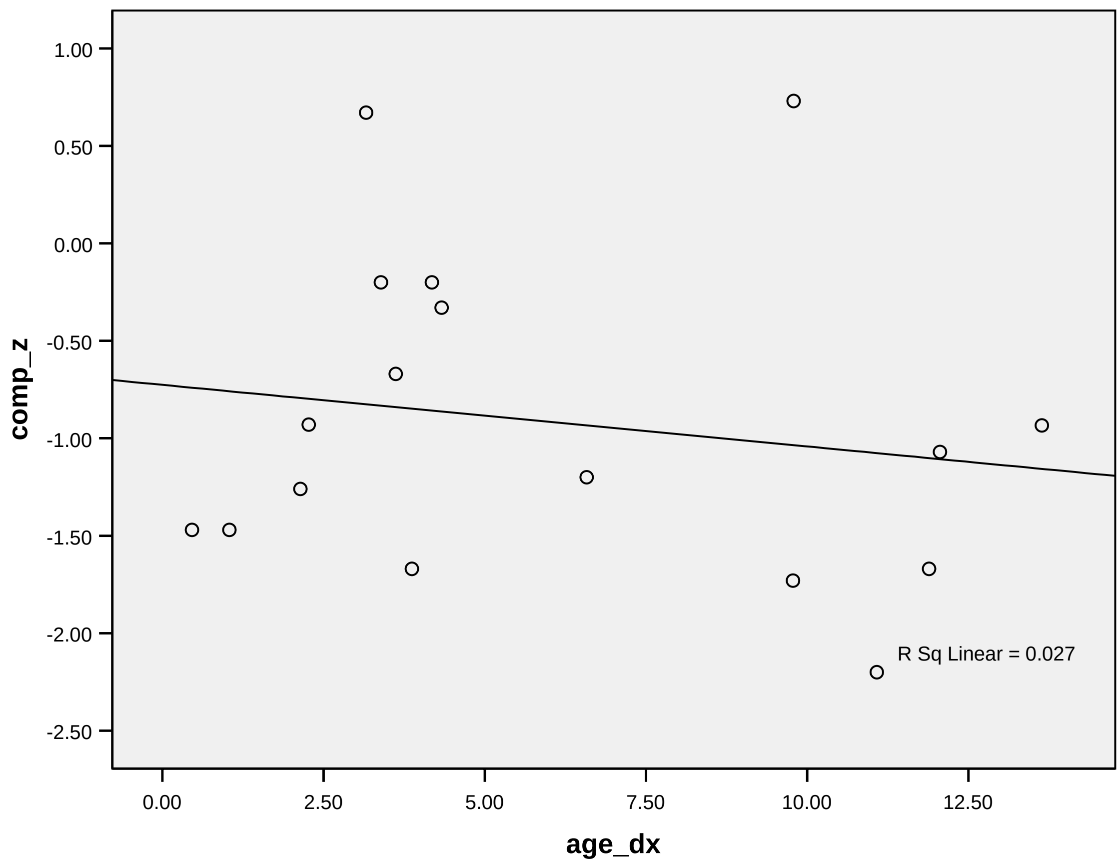
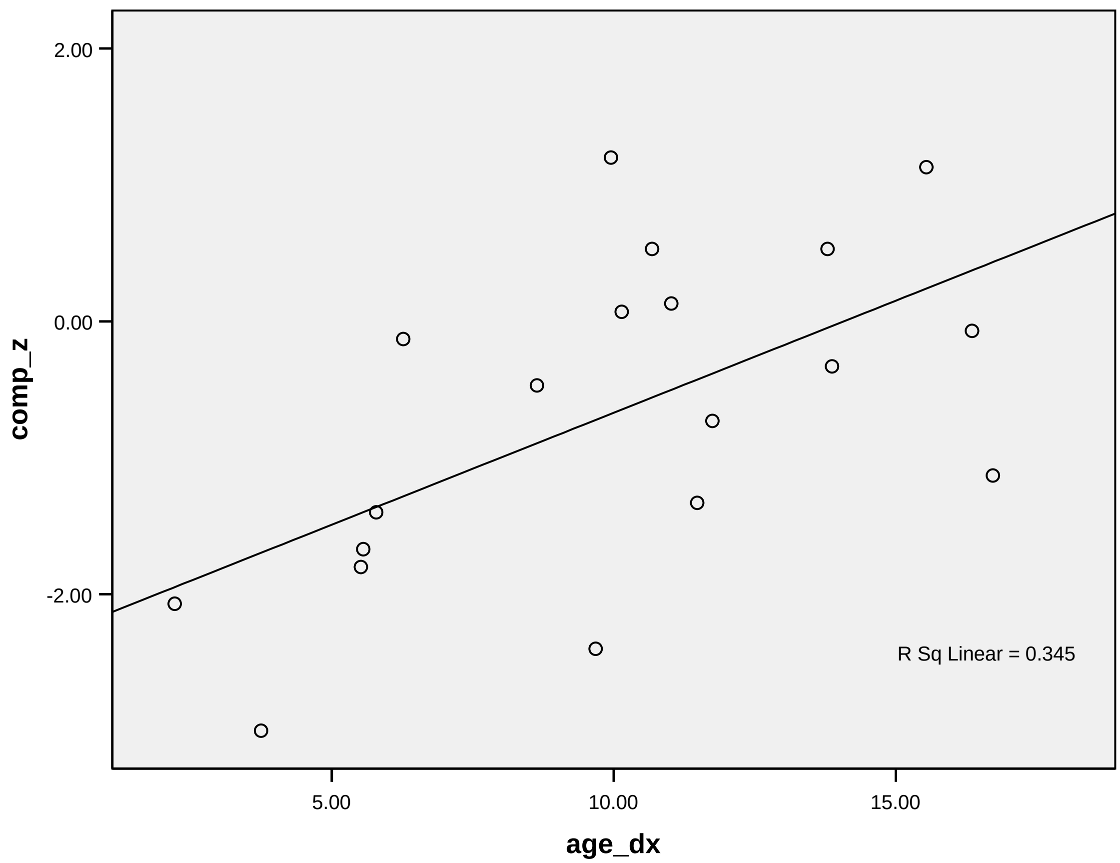


Figure 2

The Relationship between Age at Tumor Diagnosis and Z-scores on the VABS Composite for the Third Ventricle Tumor Group



relationship with the VABS Composite and age at diagnosis for the third ventricle group. However, results of the regression analyses were not significantly different with age at diagnosis entered as a covariate.

Radiation Treament.

The proportion of participants treated with radiation was not significantly different across the two tumor groups (χ^2 (1, *N* = 36) = .91, *p* = .34) (see Table 4). Six out of 17 participants with cerebellar tumors and 9 out of 19 participants with third ventricle tumors were treated with radiation (see Table 5). Radiation treatment was not significantly related to Composite z-scores (*t* (36) = .30, *p* = .77) or age-covaried raw scores (*t* (36) = -1.08, *p* = .29). The total amount of radiation received was significantly different across the two tumor groups (*t* (36) = -2.46, *p* = .02). The mean amount of radiation received was 2649.12 rads (*SD* = 2617.85) for the cerebellar group and 4606.58 rads (*SD* = 2164.95) for the third ventricle group. Total radiation dose was not significantly related to Composite z-scores (*r* = .17, *p* = .33) or age-covaried raw scores (*r* = .25, *p* = .15). The amount of time since initiation of radiation treatment was not significantly different between the two groups (*t* (36) = 1.42, *p* = .16). Time since the initiation of radiation was not significantly related to Composite z-scores (*t* (36) = -.23, *p* = .17) or age-covaried raw scores (*t* (36) = .04, *p* = .80).

The proportion of participants treated with whole brain radiation was not significantly different across the two tumor groups (*Fisher exact* (1, *N* = 36) = .54, *p* = .52). Six out of 17 participants with cerebellar tumors and 9 out of 19 participants with third ventricle tumors were treated with whole brain radiation. Whole brain radiation treatment was not significantly related to Composite z-scores (*t* (36) = -.48, *p* = .63) or age-covaried raw scores (*t* (36) = -.59, *p* = .56).

The proportion of participants treated with cranio-spinal radiation was not significantly different across the two tumor groups (*Fisher exact* (1, *N* = 36) = .39, *p* = .70).

Table 4

Chi-Square Analysis and Fisher Exact Tests for Categorical Variables

Variable	$\chi 2$	*p*	φ	*p*
Radiation Treatment	.91	.34	.16	.34
Whole-brain Radiation	.54	.52	.12	.46
Focal Radiation	5.4*	.02	.39	.02
Spinal Radiation	3.18	.07	-.30	.07
Chemotherapy	.03	1.0	-.03	.86
Neurosurgery	10.73***	.00	-.55	.00
Hydrocephalus	1.21	.41	-.18	.27
Seizure Medication	.39	.70	.10	.53

* $p < .05$
** $p < .01$
*** $p < .001$

Table 5

Number of participants exposed to potentially confounding tumor and treatment related variables by tumor location group

	Cerebellar	Third Ventricle
	N = 17	N = 19
Radiation	9	13
Whole-Brain Radiation	6	9
Cranio-Spinal Radiation	3	5
Spinal Radiation	6	2
Focal Radiation	7*	15*
Chemotherapy	4	4
Neurosurgery	17***	10***
Hydrocephalus	15	14
Seizure Medications	3	5

**p <.05*
***p <.01*
****p <.001*

Three out of 17 participants with cerebellar tumors and 5 out of 19 participants with third ventricle tumors were treated with cranio-spinal radiation. Radiation treatment was not significantly related to Composite z-scores (t (36) = .36, p = .72) or age-covaried raw scores (t (36) = -.25, p = .81).

The proportion of participants treated with focal radiation was significantly different across the two tumor groups (χ^2 (1, N = 36) = 5.39, p = .02). Seven out of 17 participants with cerebellar tumors and 15 out of 19 participants with third ventricle tumors were treated with focal radiation. Focal radiation treatment was not, however, significantly related to Composite z-scores (t (36) = .56, p = .58) or age-covaried raw scores (t (36) = -.01, p = 1.00). The dose of focal radiation given was not significantly different across the two tumor groups (χ^2 (1, N = 36) = -1.85, p = .07). However, there was a trend towards participants with tumors of the third ventricle receiving a significantly higher dose of focal radiation (M = 1662.11, SD = 1745.81) than participants with cerebellar tumors (M = 789.41, SD = 911.01). Focal radiation dose was not, however, significantly related to Composite z-scores (r = .02, p = .89) or age-covaried raw scores (r = .20, p = .24).

The proportion of participants treated with spinal radiation was not significantly different across the two tumor groups (*Fisher exact* (1, N = 36) = 3.18, p = .11). Six out of 17 participants with cerebellar tumors and 2 out of 19 participants with third ventricle tumors were treated with cranio-spinal radiation. Radiation treatment was not significantly related to Composite z-scores (t (36) = .51, p = .61) or age-covaried raw scores (t (36) = -.82, p = .42). Neither the presence of radiation nor treatment with whole brain, cranio-spinal, focal, or spinal radiation nor the amount of focal or total radiation received nor the time since the initiation of radiation treatment are considered to be confounds in this study.

Chemotherapy.

The number of participants treated with chemotherapy was not significantly different across the two tumor locations (χ^2 (1, *N* = 36) = .03, *p* = 1.00). Four out of 17 participants with cerebellar tumors and 4 out of 19 participants with third ventricle tumors were treated with chemotherapy. Chemotherapy treatment was not significantly related to Composite z-scores (*t* (36) = .51, *p* = .61) or age-covaried raw scores (*t* (36) = .40, *p* = .69). The amount of time elapsed in days since initiation of chemotherapy was not significantly different between the two groups (*t* (36) = 1.59, *p* = .12). The amount of time elapsed since chemotherapy treatment was not significantly related to Composite z-scores (*t* (36) = .10, *p* = .58) or age-covaried raw scores (*t* (36) = -.04, *p* = .80). Neither treatment with chemotherapy nor the number of days since initiation of chemotherapy treatment are considered confounds in this study.

Surgery.

The number of participants treated with neurosurgery was significantly different between the two groups (*χ2* (1, *N* = 36) = 10.74, *p* = .001). All 17 participants with cerebellar tumors whereas only 10 out of 19 participants with third ventricle tumors were treated with neurosurgery. Surgical treatment was not significantly related to Composite z-scores (*t* (36) = -1.21, *p* = .24) or age-covaried raw scores (*t* (36) = -.43, *p* = .67). Therefore, surgical resection is not considered to be a confounding variable in the current analysis.

Seizure Medication.

The number of participants prescribed seizure medication was not significantly different across the tumor groups (χ^2 (1, *N* = 36) = .39, *p* = .70). Nine out of 17 participants with cerebellar tumors and 13 out of 19 participants with third ventricle tumors were prescribed seizure medication. Being prescribed seizure medication was not significantly related to Composite z-scores (*t* (36) = -.24, *p* = .82) or age-covaried raw scores (*t* (36) = -.64, *p* = .53). Therefore, being prescribed seizure medications is not considered to be a confound in the current analyses.

Hydrocephalus.

The number of participants diagnosed with hydrocephalus was not significantly different across the tumor groups (χ^2 (1, *N* = 36) = 1.21, *p* = .41). Fifteen out of 17 participants with cerebellar tumors and 14 out of 19 participants with third ventricle tumors were diagnosed with hydrocephalus. The presence of hydrocephalus was not significantly related to Composite z-scores (*t* (36) = 1.66, *p* = .11) or age-covaried raw scores (*t* (36) = 1.16, *p* = .25). A diagnosis of hydrocephalus is not considered to be a confound in the current analyses.

Neurological Predictors Scale.

To assess the cumulative effects of treatment, total scores (*Range*: 0-11) on the Neurological Predictors Scale were calculated. The mean score for the cerebellar group was 6.41 (SD = 1.80) and the mean score for the third ventricle group was 6.11 (SD = 2.16). The mean score for the two groups was not significantly different (*t* (36) = .46, *p* = .65). Total scores showed a trend towards being related to the Composite z-scores (*r* = -.32, *p* = .06) and was not significantly related to age-covaried raw scores (*r* = -.20, *p* = .24). Therefore, scores on the Neurological Predictors Scale are not considered to be a confound in the current study.

Primary Analyses

Before conducting the regression analyses the assumptions of regression were tested. There was one outlier (an outlier was defined as a z-score greater than ± 4) within the third ventricle group on the sum of Trials 1-5 with a z-score of 4.02. When analyses were re-run without this participant, the results did not change, so this participant was kept in the remaining analyses. Descriptive statistics for performance in z-scores on the VABS as well as on the cognitive measures are presented in Table 6. Overall the third ventricle group

Table 6

Descriptive Statistics in Age-Corrected Z-scores (Cerebellum N = 17; Third Ventricle N = 19)

Variable	Mean	Std. Dev.	Minimum	Maximum	Number Impaired[a]
Cerebellum					
VABS Composite	-.92	.83	-2.20	.73	2
VABS Communication	-.75	.99	-2.87	1.20	5
VABS Daily Living Skills	-.81	.98	-2.27	1.13	0
VABS Socialization	-.23	.70	-1.40	1.13	4
PPVT	-.25	1.12	-2.27	1.20	4
RAVLT Trial 1	-.26	1.11	-2.33	1.83	2
RAVLT Trials 1-5	-.34	1.67	-3.70	2.22	3
RAVLT Delayed Recall	-.16	2.68	-3.43	3.14	3
Third Ventricle					
VABS Composite	-.68	1.41	-3.00	1.20	4
VABS Communication	-.85	1.08	-2.73	1.00	2
VABS Daily Living Skills	-.43	1.22	-3.27	1.53	3
VABS Socialization	-.20	1.04	-2.07	1.33	5
PPVT	-.18	1.47	-3.07	2.13	5
RAVLT Trial 1	.00	1.33	-1.94	1.92	2
RAVLT Trials 1-5	-.56	1.67	-4.02	2.38	6
RAVLT Delayed Recall	-.56	1.63	-2.90	1.53	7

Note. [a]Impaired performance was defined as performance at or below 1.5 standard deviations from the mean.

displayed more variability in performance on the PPVT, Trial 1, and adaptive behavior variables. Mean performance on the Daily Living Skills domain was most discrepant between the two groups (cerebellar: *M* = -.81 *SD* = .98; third ventricle: *M* = -.43, *SD* = 1.22). The cerebellar group performed on average, relatively worse than the third ventricle group on Trial 1 (cerebellar: *M* = -.26 *SD* = 1.11; third ventricle: *M* = .00, *SD* = 1.33). The third ventricle group performed relatively worse on Trials 1-5 (third ventricle: *M* = -.56, *SD* = 1.67; cerebellar: *M* = -.34 *SD* = 1.67) and the Long Delay Free Recall Trial (third ventricle: *M* = -.56, *SD* = 1.63; cerebellar: *M* = -.16 *SD* = 2.68). However, both groups were, on average, considered to be within normal limits. See Table 6 for the number of participants in each group with z-scores at or below 1.5 standard deviations from the mean.

Differences between Tumor Locations on Cognitive Measures.

In order to test if these differences between the two groups on the cognitive measures were significant, a MANOVA was conducted. More specifically, it had been hypothesized that the cerebellar group would be impaired on a measure of attention supraspan, Trial 1 of the RAVLT, relative to the third ventricle group, and that the third ventricle group would be impaired on measures of learning and memory, the sum of Trials 1-5 and the Long Delay Free Recall Trial, relative to the cerebellar group. A MANOVA was performed to determine if cognitive performance on measures of attention, learning, memory, and receptive verbal knowledge was significantly different between the two tumor groups. No variables were shown to be significantly different across tumor location (F (1, 34) = .69, p = .60).

Relationship between Cognitive Measures and Overall Adaptive Functioning.

Two regressions were conducted, one for each tumor location, to test the hypothesis that the relationship between the cognitive measures and the VABS Adaptive Behavior Composite are significantly different across tumor locations (see Table 7). Using z-scores, no cognitive measures were shown to be significant predictors of overall adaptive functioning in

Table 7

Summary of Regression Analysis for Variables Predicting the Adaptive Behavior Composite Score of the Vineland in Z-scores (N = 36)

Tumor Location	Variable	B	SE B	β	p
Cerebellum					
	PPVT	.16	.22	.22	.49
	Trial 1	.49	.33	.65	.16
	Sum Trials 1-5	-.17	.25	-.35	.51
	Delayed Recall	-.15	.24	-.29	.55
Third Ventricle					
	PPVT	.64	.12	.79	.000***
	Trial 1	.04	.19	.04	.85
	Sum Trials 1-5	-.03	.19	-.04	.90
	Delayed Recall	.23	.16	.31	.16

Note. R^2 = .22 for the Cerebellum group; R^2 = .76 (p< .001) for the Third Ventricle group.
* *p < .05*
** *p < .01*
*** *p < .001*

the cerebellar group (R^2 = .22, *p* = .51). Trial 1 was the best predictor of performance with a large effect size (β = .65, *p* = .16), however, this variable was not strong enough to be a significant effect owing to a lack of sufficient power. The PPVT was the only significant predictor of overall adaptive functioning in the third ventricle group (β = .79, p < .001) and the overall model accounted for 76% of the variance in adaptive functioning performance (R^2 = .76, p < .001).

In order to test whether the effect sizes for any of the cognitive measures were significantly different between the two tumor groups. Interaction terms between tumor location and the cognitive z-scores were entered at step 2 of the regression. The PPVT displayed a trend towards differing significantly in its predictive ability across groups (β = .49, *p* = .06) and was able to explain much more variance in the third ventricle group than the cerebellar group. Given that Trial 1 and the sum of Trials 1-5 are likely to share some error variance because they both include performance on the first trial of the RAVLT, hierarchical regressions were re-run with the sum of Trials 1-5 removed from the analyses. Removing this independent variable did not appreciably change the overall predictive power of the model nor the relative importance of any of the other cognitive measures.

In order to further explicate what it is about the PPVT that makes it such a good predictor of adaptive functioning for the third ventricle group, analyses were re-run replacing PPVT z-scores with z-scores of general IQ and again with general reading achievement. A very similar pattern was observed with the SB-IV Overall Composite IQ displaying strong predictive power for the third ventricle group (β = .84, p < .001) and poor predictive power for the cerebellar group (β = .08, *p* = .78). Given the differences in mean age between the two groups and therefore the differential average amount of schooling received by the two groups, scores on the Wide Range Achievement Test (WRAT) reading subtest were entered as a measure of academic achievement along with Trial 1, the sum of Trials 1-5, and the delayed recall trial. Performance on the WRAT reading subtest was not significantly associated with adaptive functioning performance for the cerebellar group (β = -.54, p = .15), but was significantly associated with overall adaptive functioning for the third ventricle group (β = .63, p < .01) (see Figures 3 and 4).

Parallel analyses were run using age-covaried raw scores (see Table 8). The amount of variance accounted for by the model for the cerebellar group decreased ($R^2\Delta$ = .11, p = .26), and it decreased even more noticeably for the third ventricle groups ($R^2\Delta$ = .12, p = .005). There were no significant effects for the cerebellar group, however Trial 1 (β = .48, p = .15) explained a large amount of variance. With a larger sample, and therefore more power, this effect would have been significant. Within the third ventricle group, the PPVT was a significant predictor of overall adaptive functioning (β = .40, p = .03).

Relationship between Cognitive Measures and the Communication Domain.

Two regressions were conducted, one for each tumor location, to test the hypothesis that the relationship between the cognitive measures and the VABS Communication domain was significantly different for the two tumor locations (see Table 9). Trial 1 was a significant predictor of performance on the Communication domain for the cerebellar group (β = .81, p = .05) and the overall model accounted for a large amount of variance in performance (R^2 = .43, p = .12). The PPVT was the only significant predictor of performance for the third ventricle group (β = .61, p = .02). The overall model was able to explain 40% of the variance in the third ventricle group (R^2 = .40, p = .11). Interaction terms between tumor location and the cognitive measures revealed a trend towards significance for Trial 1 with it having greater predictive power for the cerebellar group (β = -.72, p = .06). Removing the sum of Trials 1-5 from the model did not appreciably change the results for either tumor location.

As with the Adaptive Behavior Composite, replacing the PPVT with the Composite IQ score from the SBIT-IV revealed that both measures are able to account for similar

Figure 3

The Relationship between the VABS Composite and WRAT Reading subtest in z-scores for the Cerebellar Tumor Group

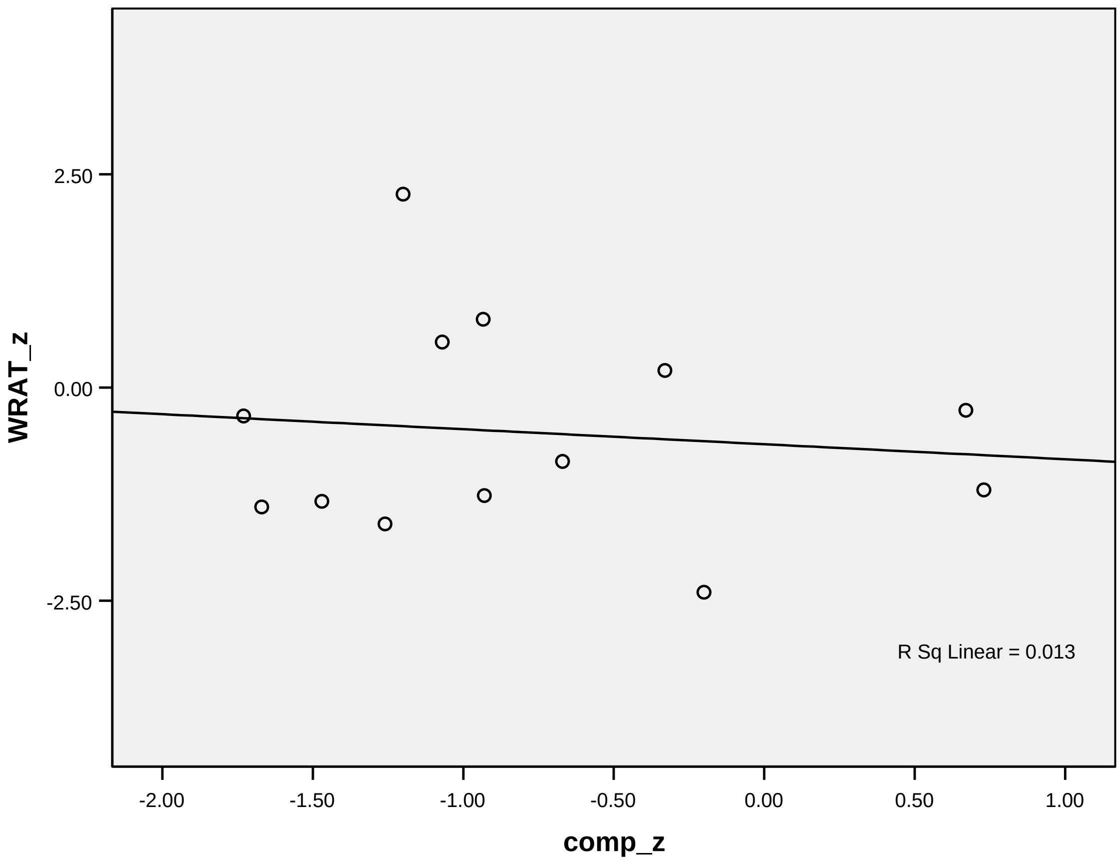


Figure 4

The Relationship between the VABS Composite and WRAT Reading subtest in z-scores for the Third Ventricle Tumor Group

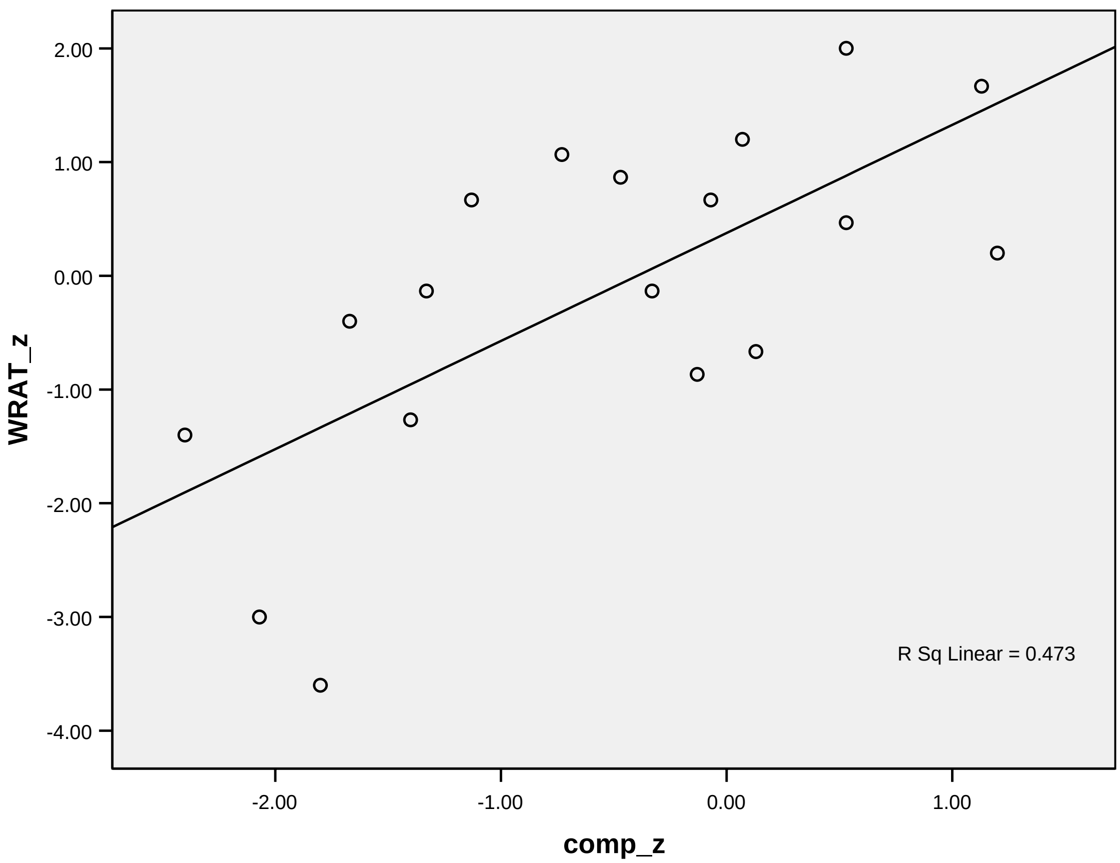


Table 8

Summary of Regression Analysis for Variables Predicting the Adaptive Behavior Composite Score of the Vineland using Age-Covaried Raw Scores (N = 36)

Tumor Location	Variable	B	SE B	β	p
Cerebellum					
	PPVT	.03	.49	.02	.96
	Trial 1	12.07	7.79	.48	.15
	Sum Trials 1-5	.53	1.19	.17	.66
	Delayed Recall	-5.52	3.35	-.54	.13
Third Ventricle					
	PPVT	.73	.30	.40	.03*
	Trial 1	3.42	4.31	.10	.44
	Sum Trials 1-5	.97	1.08	.18	.39
	Delayed Recall	-.52	2.06	-.03	.81

Note. $R^2\Delta$ = .11 for the Cerebellum group; $R^2\Delta$ = .12 (p< .01) for the Third Ventricle group.
**p <.05*
***p<.01*
****p<.001*

Table 9

Summary of Regression Analysis for Variables Predicting the Communication Domain Score of the Vineland in Z-scores (N = 36)

Tumor Location	Variable	B	SE B	β	p
Cerebellum					
	PPVT	.17	.23	.20	.46
	Trial 1	.72	.34	.81	.05*
	Sum Trials 1-5	.01	.25	.01	.99
	Delayed Recall	-.27	.24	-.44	.29
Third Ventricle					
	PPVT	.45	.17	.61	.02*
	Trial 1	-.17	.27	-.18	.55
	Sum Trials 1-5	-.19	.28	-.29	.51
	Delayed Recall	.28	.22	.42	.23

Note. R^2 = .43 for the Cerebellum group; R^2 = .40 for the Third Ventricle group.
* *p < .05*
** *p < .01*
*** *p < .001*

amounts of variance in Communication domain scores. For the cerebellar group the PPVT (β = .20, p = .46) was replaced with the SBIT-IV IQ (β = .25, p = .30) resulting in similar effect sizes for the two variables. Similarly, when the PPVT (β = .61, p = .02) was replaced with the SBIT-IV IQ (β = .59, p = .04) in the third ventricle group nearly identical amounts of variance were explained. Replacing PPVT scores with the WRAT reading subtest scores revealed a weak relationship for the cerebellar group (β = -.10, p = .72), but increased the amount of variance this model was able to account for from 43% to 65% (p = .06). Within the third ventricle group, WRAT reading scores were a significant predictor of performance on the Communication domain (β = .63, p = .01) and increased the amount of variance accounted for by the model from 40% to 60% (p = 01).

Parallel analyses were conducted using age-covaried raw scores (see Table 10). The amount of variance accounted for by the model for the cerebellar group decreased ($R^2\Delta$ = .11, p = .19), and it decreased even more noticeably for the third ventricle group ($R^2\Delta$ = .12, p = .03). There were no significant effects for the cerebellar group. Within the third ventricle group, the PPVT showed a trend towards being a significant predictor of overall adaptive functioning (β = .45, p = .06).

Relationship between Cognitive Measures and the Daily Living Skills Domain.

Two regressions were conducted, one for each tumor location, to test the hypothesis that the relationship between the cognitive measures and the VABS Daily Living Skills domain was significantly different for the two tumor locations (see Table 11). There were no significant predictors for the cerebellar group, and the overall model accounted for 11% of the variance in performance (R^2 = .11, p = .84). The PPVT was the only significant predictor of performance for the third ventricle group (β = .64, p = .006). The overall model was able to explain a large amount of variance (R^2 = .57, p = .01) the third ventricle group. No interaction terms between tumor location and the cognitive measures were significant. Removing the

Table 10

Summary of Regression Analysis for Variables Predicting the Communication Domain Score of the Vineland using Age-Covaried Raw Scores (N = 36)

Tumor Location	Variable	B	SE B	β	p
Cerebellum					
	PPVT	.19	.15	.37	.21
	Trial 1	2.39	2.34	.28	.33
	Sum Trials 1-5	.07	.36	.06	.85
	Delayed Recall	-.58	1.00	-.17	.58
Third Ventricle					
	PPVT	.26	.13	.45	.06
	Trial 1	.50	1.78	.04	.78
	Sum Trials 1-5	.32	.45	.19	.49
	Delayed Recall	-.28	.85	-.06	.75

Note. $R^2\Delta$ = .11 for the Cerebellum group; $R^2\Delta$ = .12 ($p<.05$) for the Third Ventricle group.
* *p < .05*
** *p < .01*
*** *p < .001*

Table 11

Summary of Regression Analysis for Variables Predicting the Daily Living Skills Domain Score of the Vineland in Z-scores (N = 36)

Tumor Location	Variable	B	SE B	β	p
Cerebellum					
	PPVT	.07	.28	.08	.81
	Trial 1	.40	.42	.45	.36
	Sum Trials 1-5	-.01	.32	-.01	.99
	Delayed Recall	-.22	.30	-.37	.47
Third Ventricle					
	PPVT	.53	.16	.64	.006**
	Trial 1	.31	.26	.29	.25
	Sum Trials 1-5	.03	.27	.05	.90
	Delayed Recall	-.01	.21	-.01	.98

Note. R^2 = .11 for the Cerebellum group; R^2 = .57 (p = .01) for the Third Ventricle group.
* $p < .05$
** $p < .01$
*** $p < .001$

sum of Trials 1-5 from the model did not appreciably change the results for either tumor location.

As with the Adaptive Behavior Composite, replacing the PPVT with the Composite IQ score from the SBIT-IV revealed that both measures are able to account for similar amounts of variance in Daily Living Skills domain scores. For the cerebellar group the PPVT (β = .08, p = .81) was replaced with the SBIT-IV IQ (β = -.09, p = .78) the effect sizes were small for both variables, although there was a slight negative association between IQ scores and performance on the Daily Living Skills domain. When the PPVT (β = .53, p = .006) was replaced with the SBIT-IV IQ (β = .67, p = .007) in the third ventricle group each measure was able to explain large amounts of variance. Replacing PPVT scores with the WRAT reading subtest scores revealed a strongly inverse relationship for the cerebellar group (β = -.54, p = .18) and increased the amount of variance this model was able to account for from 11% to 32% (p = .48). Within the third ventricle group, WRAT reading scores displayed a trend towards being a significant predictor of performance on the Daily Living Skills domain (β = .50, p = .06), and the amount of variance accounted for by this model dropped from 57% to 41% (p = .12).

Parallel analyses were conducted using age-covaried raw scores (see Table 12). The amount of variance accounted for by the model for the cerebellar group increased ($R^2\Delta$ = .27, p = .19), and it decreased noticeably for the third ventricle group ($R^2\Delta$ = .13, p = .03). There were no significant effects for either group.

Relationship between Cognitive Measures and the Socialization Domain.

Two regressions were conducted, one for each tumor location, to test the hypothesis that the relationship between the cognitive measures and the VABS Socialization domain were significantly different for the two tumor locations (see Table 13). There were no significant predictors for the cerebellar group, and the overall model accounted for 38% of

Table 12

Summary of Regression Analysis for Variables Predicting the Daily Living Skills Domain Score of the Vineland using Age-Covaried Raw Scores (N = 36)

Tumor Location	Variable	B	SE B	β	p
Cerebellum					
	PPVT	-.26	.40	-.30	.52
	Trial 1	7.14	6.36	.50	.29
	Sum Trials 1-5	1.03	.97	.56	.31
	Delayed Recall	-4.21	2.73	-.73	.15
Third Ventricle					
	PPVT	.28	.17	.36	.12
	Trial 1	3.12	2.39	.21	.21
	Sum Trials 1-5	.36	.60	.16	.56
	Delayed Recall	-.68	1.14	-.10	.56

Note. $R^2\Delta$ = .27 for the Cerebellum group; $R^2\Delta$ = .13 ($p < .05$) for the Third Ventricle group.
* *p < .05*
** *p < .01*
*** *p < .001*

Table 13

Summary of Regression Analysis for Variables Predicting the Socialization Domain Score of the Vineland in Z-scores (N = 36)

Tumor Location	Variable	B	SE B	β	p
Cerebellum					
	PPVT	.06	.17	.10	.72
	Trial 1	.19	.25	.30	.47
	Sum Trials 1-5	-.20	.19	-.48	.31
	Delayed Recall	-.18	.18	-.42	.33
Third Ventricle					
	PPVT	.46	.13	.66	.003**
	Trial 1	-.09	.20	-.46	.66
	Sum Trials 1-5	.01	.21	.02	.95
	Delayed Recall	.25	.17	.40	.15

Note. R^2 = .38 for the Cerebellum group; R^2 = .64 (p< .01) for the Third Ventricle group.
* *p < .05*
** *p < .01*
*** *p < .001*

the variance in performance (R^2 = .38, *p* = .19). The PPVT was the only significant predictor of performance for the third ventricle group (*β* = .66, *p* = .003). The overall model was able to explain a large amount of variance (R^2 = .64, *p* = .004) within the third ventricle group. Interaction terms between tumor location and the cognitive measures revealed a trend towards the PPVT (*β* = .49, *p* = .07) and Long Delay Free Recall trial (*β* = .59, *p* = .09) being significantly better predictors of Socialization domain scores for the third ventricle group than the cerebellar group. Removing the sum of Trials 1-5 from the model did not appreciably change the results for either tumor location.

Replacing the PPVT with the Composite IQ score from the SBIT-IV revealed that both measures are able to account for similar amounts of variance in Socialization domain scores. For the cerebellar group the PPVT (*β* = .10, *p* = .72) was replaced with the SBIT-IV IQ (*β* = -.08, *p* = .74) the effect sizes were similar for the two variables. When the PPVT (*β* = .66, *p* = .003) was replaced with the SBIT-IV IQ (*β* = .71, *p* = .002) in the third ventricle group each measure was able to explain large amounts of variance. Replacing PPVT scores with the WRAT reading subtest scores revealed a strongly inverse relationship for the cerebellar group (*β* = -.42, *p* = .27) and the amount of variance this model was able to account for was 37% (down 1% from the model with PPVT scores). Within the third ventricle group, WRAT reading scores displayed a trend towards being a significant predictor of performance on the Daily Living Skills domain (*β* = .41, *p* = .08), and the amount of variance accounted for by this model dropped from 64% to 55% (*p* = .03).

Parallel analyses were conducted using age-covaried raw scores (see Table 14). The amount of variance accounted for by the model for the cerebellar group decreased ($R^2\Delta$ = .16, *p* = .08) compared to z-scores, and it decreased noticeably for the third ventricle group ($R^2\Delta$ = .13, *p* = .01). The sum of Trials 1-5 displayed a trend towards significance for the cerebellar

Table 14

Summary of Regression Analysis for Variables Predicting the Socialization Domain Score of the Vineland using Age-Covaried Raw Scores (N = 36)

Tumor Location	Variable	B	SE B	β	p
Cerebellum					
	PPVT	.10	.11	.23	.41
	Trial 1	2.54	1.82	.38	.19
	Sum Trials 1-5	-.56	.28	-.64	.07
	Delayed Recall	-.73	.78	-.27	.37
Third Ventricle					
	PPVT	.19	.10	.35	.09
	Trial 1	-.20	1.44	-.02	.89
	Sum Trials 1-5	.29	.36	.19	.44
	Delayed Recall	.44	.69	.10	.53

Note. $R^2\Delta = .16$ for the Cerebellum group; $R^2\Delta = .13$ (p= .01) for the Third Ventricle group.
* *p < .05*
** *p < .01*
*** *p < .001*

group (β = -.64, p = .07), and within the third ventricle group the PPVT displayed a trend towards significance (β = .35, p = .09).

Attention as Moderator of PPVT Performance.

As the PPVT-R has been shown to have an attentional component (Dunn & Dunn, 1997), and there were differences in the average attention supraspan between the two groups, the role of attention as a moderator of the relationship between the PPVT-R and overall adaptive functioning performance was explored. Performance on Trial 1 and the PPVT in z-scores was centered using the mean and these variables were entered at step 1 of the regression while the product of these two variables was entered at step 2. This interaction term, entered at step 2, was not significant ($R^2\Delta$ = .003, p = .69) indicating that attention does not act as a significant moderator of the relationship between PPVT scores and performance on the Adaptive Behavior Composite.

Cognitive Performance as a Mediator of the Relationship between Treatment Variables and Overall Adaptive Functioning.

To assess the hypothesis that the relationship between adaptive functioning and the treatment variables of time since diagnosis, age at diagnosis, the presence of hydrocephalus, and treatment with chemotherapy and radiation is mediated by performance on the cognitive measures a mediational model was tested. The first regression explored the ability of the treatment related variables to predict the Adaptive Behavior Composite score, and no treatment variables were found to be significantly related to the Composite score (R^2 = .16, p = .38). Therefore, as per Baron & Kenny (1986), testing of this mediational model was discontinued.

In order to assess the possible cumulative effects of treatment, an exploratory mediational model was conducted using the Neurological Predictors Scale created by Micklewright et al. (2006). Although the total score on this scale displayed a trend towards a significant relationship with overall adaptive functioning (R^2 = .10, p = .06), this score was not significantly associated with performance on any of the cognitive measures so testing of this model was discontinued.

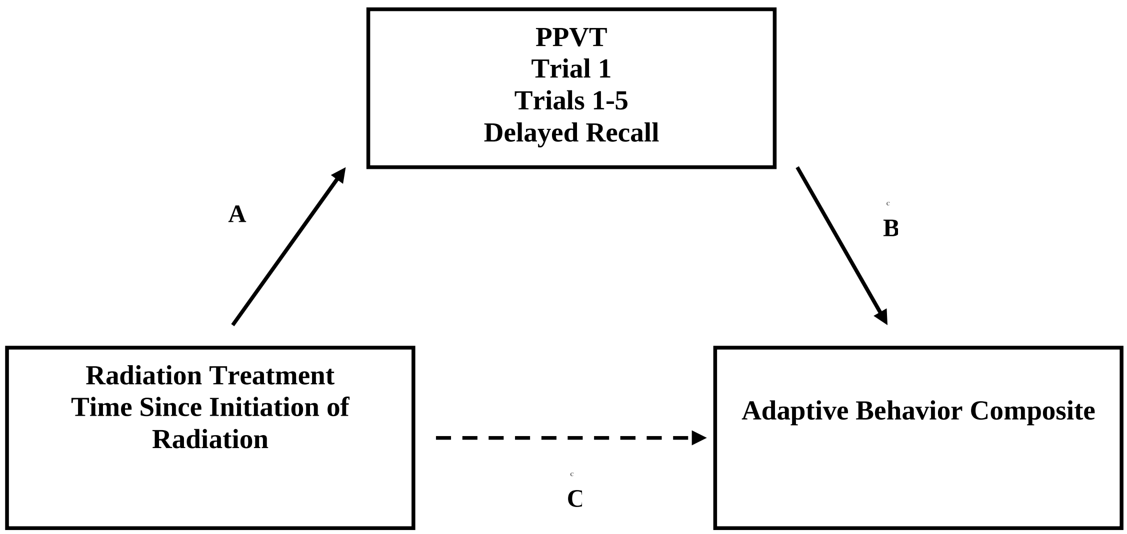
Given the profound effects radiation has been shown to have on cognitive performance (Dennis et al, 1998; Ellenberg et al., 1987; Fletcher & Copeland, 1988; Moore et al., 1992), an additional exploratory mediational model was conducted using whether participants were treated with radiation and the amount of time elapsed since radiation (see Figure 5). These two variables were first tested for multicollinearity, which was not found (r = .46, p < .01). The first regression assessed the ability of these two treatment variables to predict z-scores on the Adaptive Behavior Composite. Time since radiation was significantly and negatively associated with Composite scores (β = -.38, p = .05) while treatment with radiation was positively associated with the Composite (β = .25, p = .18). Time since radiation was a significant predictor of performance on the PPVT (β = -.39, p = .03) and Trial 1 (β = -.58, p = .001). When testing the significance of the relationship between the cognitive measures and the Composite score, only the PPVT was a significant predictor (β = .61, p = .000). In order to test for mediation, in the final regression the cognitive measures were entered at step 1, followed by time since radiation and total dose of radiation at step 2 (see Table 15). In this regression, time since radiation dropped from significance indicating the presence of full mediation (β = -.07, p = .72)

Cognitive and Adaptive Functioning, and Treatment as Predictors of Tumor Location.

A discriminant function analysis was conducted to determine how well cognitive and adaptive functioning and treatment variables could predict tumor location. This allowed us to determine the variables on which the two tumor location groups differ the most. The following variables were used as independent variables: scores on the three Adaptive Functioning domains, Trial 1, Long Delay Free Recall, as well as time since diagnosis, the

Figure 5

Exploratory Mediational Model with Cognitive Performance as a Mediator of the Relationship between Radiation Treatment Variables and Overall Adaptive Functioning



Note. **Pathway A:** Time since radiation was a significant predictor of PPVT (β = -.39, p = .03) and Trial 1 (β = -.58, p = .001) scores.

Pathway B: PPVT scores were a significant predictor of the Adaptive Behavior Composite (β = .61, p = .000).

Pathway C: Time since radiation was significantly related to performance on the Adaptive Behavior Composite (β = -.30, p = .05).

Pathway AB: When controlling for the effects of cognitive performance, time since radiation was no longer a significant predictor of the Adaptive Behavior Composite (β = -.07, p = .72) indicating the presence of full mediation.

Table 15

Summary of Model to test if Cognitive Performance Mediates the Relationship between Treatment Variables and the Adaptive Behavior Composite Score of the Vineland in Z-scores (N = 36)

	Variable	B	SE B	β	pr2	sr2	p
Step1							
	PPVT	.48	.12	.61	.60	.57	.000***
	Trial 1	.09	.18	.10	.09	.07	.61
	Sum Trials 1-5	.01	.17	.02	.01	.01	.95
	Delayed Recall	.00	.14	.00	.00	.00	1.00
Step 2							
	Time since Radiation	.00	.00	-.07	-.07	-.05	.72
	Treatment with Radiation	.70	.34	.32	.36	.27	.05*

Note. Step 1 $R^2 = .42$ ($p = .002$); $R^2\Delta = .08$ ($p < .12$)
*$p < .05$
**$p < .01$
***$p < .001$

presence of hydrocephalus or a seizure disorder, and treatment with radiation, chemotherapy, or surgery. In testing the equality of group means, only surgery was significantly different between the two groups ($\lambda = .53$, $F(1, 34) = 14.45$, $p = .001$). The canonical correlation, or correlation between the independent variables and tumor location was .74 indicating that that these independent variables discriminate well. 86.1% of cases were correctly classified (see Table 16).

Given the significant age differences between the two groups, an additional discriminant analysis with age at diagnosis as the only independent variable was conducted to ensure that the above model was not simply capitalizing on this difference. Age was significantly different between the two groups ($\lambda = .82$, $F(1, 34) = 7.26$, $p = .01$). The canonical correlation was .42 indicating that that age discriminates moderately well. Using this model with age at diagnosis as the only predictor, 66.7% of cases were correctly classified. This high percentage of correct classification using only age at diagnosis, indicated that this variable likely accounted for a great deal of the variance in our initial discriminant model.

Discussion

Contrary to our hypotheses, no significant differences were found between the cerebellar and third ventricle tumors groups in performance on cognitive measures of attention, learning, memory, and receptive verbal knowledge. Nevertheless, there were significant differences between the two tumor groups on how well these cognitive measures were able to predict overall adaptive functioning. Our model accounted for much more of the variance in the third ventricle group when compared to the cerebellar group. In addition, there were different cognitive predictors of adaptive functioning by group. As hypothesized for the cerebellar group, performance on Trial 1 of the RAVLT, a measure of attention, was a strong predictor of adaptive skills within the Communication and Socialization domains, and was

Table 16

Summary of the Discrimant Function Analysis Classifications (N = 36) with Adaptive Functioning, Cognitive Performance, and Treatment Variables used as Predictors

		Predicted Group Membership	
Actual Group Membership		Cerebellum	Third Ventricle
Cerebellum			
	Count	16	1
	Percentage	94.1	5.9
Third Ventricle			
	Count	4	15
	Percentage	21.1	78.9

Note. 86.1% of cases were correctly classified.

Summary of the Discrimant Function Analysis Classifications (N = 36) Using Age as the Only Predictor

		Predicted Group Membership	
Actual Group Membership		Cerebellum	Third Ventricle
Cerebellum			
	Count	11	6
	Percentage	64.7	35.3
Third Ventricle			
	Count	6	13
	Percentage	31.6	68.4

Note. 66.7% of cases were correctly classified.

also the best predictor of adaptive functioning on the Daily Living Skills domain. Within the third ventricle group, memory abilities were a strong predictor of performance on the Socialization domain, but not the Daily Living Skills domain. Learning ability, however, was not a strong predictor of performance on any domain. Contrary to our hypotheses, the PPVT was the best predictor of adaptive functioning skills across all three domains and the Composite for the third ventricle group. Lastly, the proposed model in which cognitive performance mediated the relationship between specified treatment variables and adaptive functioning performance was not supported.

Treatment and Medical Variables

Prior to making between group comparisons based on tumor location, the potentially differential exposure to treatment and medical variables, which may exert widespread effects on functioning, was examined. Significant differences were found between the two groups in the number of participants treated with neurosurgery and the amount of radiation received. Children with third ventricle tumors received more than 1.5 times the amount of radiation given to children with cerebellar tumors. Treatment is determined by a variety of characteristics including histological grade, neuroanatomical location, tumor radiosensitivity, patient age, and clinical presentation (Suh & Mapstone, 2001). These treatment differences between the two groups may reflect the neuroanatomical locations of these regions of the brain. The cerebellum is easily accessed in surgery, and therefore surgical resection is often the first treatment modality offered to these children. Lying deep within the cerebral hemispheres and surrounded by delicate subcortical structures, surgical resection within the third ventricle region may be less feasible. In light of the long-term sequelae and morbidity in young children treated with radiation, the older mean age at diagnosis in the third ventricle group also could explain why radiation treatment may have been a more strongly favored treatment strategy in this group.

Age at tumor diagnosis was significantly different between the two groups. On average, participants in the cerebellar group were diagnosed when they were nearly four years younger than participants in the third ventricle group. This age difference does not appear to be unique to this study, but rather is likely a reflection of the differential rates of tumor location by age as well as differences in the rate at which tumors may become symptomatic. The cerebellum is the most common location for tumors in children less than 10 years of age. Furthermore, tumors in this area may become symptomatic quickly as they have little space in which to grow before blocking the drainage of cerebrospinal fluid and causing hydrocephalus. Ventricular tumors, including those in the third ventricle region, tend to grow slowly and may remain clinically silent and reach a significant size before becoming symptomatic (Suh & Mapstone, 2001).

No potential confounds were shown to be significantly related to overall adaptive functioning performance, however, age at diagnosis displayed a trend towards a significant relationship. Adaptive functioning abilities appeared to be higher in children who are diagnosed at later ages. This trend suggests that the older children are when they are diagnosed and treated for a brain tumor the better the prognosis in terms of independent living skills. Nevertheless, none of the 15 variables considered potential confounds were found to meet criteria to be considered a confound in the current study. The power to detect significant effects in this study was adequate at .80, but not likely sufficient to detect the presence of small effects. Therefore, it is possible that the lack of confounds found in this study is due to the lack of sufficient power.

Adaptive and Cognitive Functioning by Tumor Location

Overall, the third ventricle group displayed a greater level of variability in adaptive functioning skills as well as attention and verbal/general cognitive abilities. This may be a reflection of the more variable age range, and therefore the more variable levels of schooling, in this group. It is possible that this variability also could be a result of within group variations in tumor pathology. Tumor location was not able to significantly predict performance on any cognitive measure suggesting that the differences in performance on these measures are not sufficient in magnitude. Although performance did not differ significantly between the two groups on any cognitive measure, a comparison of performance on these tasks did show a subtle trend in the directions hypothesized. This is in contrast to other studies which have found significant relative impairments in learning and memory abilities in children with third ventricle tumors, whereas children with cerebellar tumors displayed significant relative impairments in attention (Micklewright et al., 2006; King et al., 2004). It may be that there was not sufficient power within this study to find significant differences, or that differences in age of diagnosis or age at evaluation in study participants influenced these different results.

Adaptive functioning skill levels were similar for both groups and fell in the average to low average range. Unlike Poggi et al. (2005) whose pediatric brain tumor sample displayed the greatest impairments in the Socialization domain, the opposite was found in this study with both tumor groups being least impaired on this domain. This difference might be due to Poggi et al.'s examination of adaptive functioning across specific age ranges (0-6; 7-13; 14-18 years at time of testing) as well as different amounts of time elapsed since diagnosis (M = 1.2, SD = 1.1; M = 2.9, SD = 2.7; M = 10.1, SD = 6.4 respectively); as compared to the current study (M = 2.42, SD = 2.2).

Cognitive Predictors of Adaptive Functioning

Although there were no significant differences in performance, the best predictors of adaptive functioning for the two groups differed. For the third ventricle group, performance on the PPVT was a robust predictor of adaptive functioning across adaptive functioning domains, whereas for the cerebellar group, performance on Trial 1 of the RAVLT was the strongest predictor across the Adaptive Behavior Composite and all three of the domains. Attention was not shown to act as a moderator of the relationship between PPVT scores and adaptive functioning. Within the third ventricle group, the strong predictive power of the PPVT is comparable to the findings of Papazoglou et al. (2006) who showed that measures of receptive, as well as expressive, verbal knowledge were good predictors of later adaptive functioning in children with brain tumors. Nevertheless, the predictive utility of the PPVT across all domains was not anticipated, and led to post-hoc analyses to better understand what it was about the PPVT that caused it to be a consistently strong predictor of adaptive functioning in the third ventricle group. When PPVT scores were replaced with SB-IV Composite IQ scores or WRAT Reading scores, the same strong predictive ability was found. This suggests that, for children with tumors in this region, the high predictive power of the PPVT may be a reflection of its ability to assess general cognitive functioning and academic achievement, as well as receptive verbal knowledge (Dunn & Dunn, 1981). This relationship between cognitive and adaptive functioning also has been shown in children with autism (Carpentieri & Morgan, 1996; Schatz & Hamdan-Allen, 1995).

This same relationship, however, was not observed within the cerebellar group. Indeed, within this group neither PPVT, SB-IV Composite, nor WRAT reading scores were as strongly associated with adaptive functioning performance. Within this sample, given their younger age at evaluation, participants with cerebellar tumors are likely to have had little, if any formal schooling prior to diagnosis, which may account for some of the discrepancy. The poor predictive utility of the SB-IV Composite, however, which should not be highly dependent on formal education is surprising. Adaptive functioning has been proposed to be more highly related to cognitive functioning at lower levels of functioning within some neurological populations (Liss et al., 2001), however, on average, both groups within our sample were functioning at average levels relative to same age peers. Future studies should seek to further explore this finding, particularly to assess whether the relationship between general cognitive and adaptive functioning varies according to tumor location or whether the between group differences observed in this study might be a reflection of the younger age of diagnosis for the cerebellar group. It is also conceivable that some other variable could be accounting for these differences.

There was a consistent trend towards a relationship between attentional abilities and adaptive functioning in the cerebellar group, however, the power of this study was not sufficient to detect a significant effect across all of the domains. Within this group, performance on Trial 1 was most strongly related to the Communication domain followed by the Daily Living Skills and Socialization domains. This is not surprising given the attentional abilities needed to attend to what someone else is saying and to be able to respond in a coherent and relevant fashion, to write a paper for school, to maintain personal hygiene, to utilize personal safety skills, to relate and respond to others, and to be a friend all require the ability to focus attention (Lezak, 2004). The strong relationship between attention and adaptive behavior in the cerebellar group suggest that this relationship warrants further study.

Contrary to our hypotheses, learning as measured by the sum of Trials 1-5 on the RAVLT was not a significant predictor of adaptive functioning on any domain for the third ventricle group. Given the average performance on this measure by both tumor groups, it is possible that in the absence of learning deficits, other measures of cognitive ability are better predictors of adaptive functioning. As was hypothesized, memory performance was related to the Socialization domain for the third ventricle group, but contrary to our hypotheses, it was not related to performance on the Daily Living Skills domain. Verbal memory abilities also were strongly related to the Communication domain. Effective communication skills depend upon the ability to remember verbally presented information. Language also serves as the principal way by which children receive guidance about social rules. For example, Halle and

Shatz (1994) showed that 25% of maternal speech to infants was concerned with the regulation of behavior, especially social behavior, through the use of instructions, questions, assertion of authority, and statements about possession rights. The Daily Living Skills domain assesses skill level in areas such as personal hygiene, household chores, and the use of money. It could be that the measure of verbal memory used was not a strong predictor of adaptive ability level within this domain because performance may be more dependent on skills such as implicit memory and motor ability. It is also possible that the small and non-significant effects of verbal learning and adaptive functioning were due to a lack of sufficient power in the current study.

Our model was able to account for substantially more variance in adaptive functioning performance on the Composite as well as the Daily Living Skills and Socialization domains for the third ventricle group. Given the differences in age at diagnosis, it is not possible to say whether this stronger relationship is a reflection of tumor location or the different average age of diagnosis between the two groups. Interaction effects showed the significantly greater predictive utility of Trial 1 for the Cerebellar group within the Communication domain suggesting that within this domain, attentional abilities are a much better predictor of adaptive functioning for children with cerebellar tumors. A trend towards significance for the greater predictive utility of the PPVT for the third ventricle group as compared to the cerebellar group within both the Composite and the Daily Living Skills domain was evident.

Negative standardized regression coefficients (beta weights) were often observed for Trials 1-5 and the Long Delay Free Recall Trial. Beta weights show the average amount the dependent variable changes when the independent variable increases one standard deviation and other independent variables are held constant. A negative beta weight indicates that as the independent variable increases one standard deviation with the other independent variables held constant, adaptive functioning performance decreases. Beta weights change when independent variables are added to or deleted from the model, and assess the unique importance of independent variables relative to the model being tested. Examination of the partial correlations for variables with negative betas showed that when the effects of the other independent variables in the model are partialed out of that variable as well as out of adaptive functioning performance, then the relationship between that variable and adaptive functioning was negative. Visual inspection of the relationship between each of these variables and adaptive functioning performance, however, indicated that when other cognitive variables are not included in the model, the relationships are positive. This suggests that our model may be underestimating the importance of the sum of Trials 1-5 and Long Delayed Free Recall, which may make strong joint contributions (together with the other independent variables) towards explaining the dependent variable, but do not always appear to make a strong unique contribution within the context of this model. This effect may be further exacerbated by a lack of sufficient power in this study.

Parallel analyses were run using both z-scores and age-covaried raw scores. Differences were observed in the results which are likely a reflection of variations in the normative groups used to standardize scores for each measure as well as how these two methods view the influence of age. A compilation of norms was used to determine z-scores for the RAVLT and the number of children on whom the norms for each age were based varied. The standardization of PPVT performance was much more rigorous in comparison, with larger groups of children as well as a better geographic and socioeconomic representation of children across the United States (Dunn & Dunn, 1981). Additionally, there are differences between how these two methods view the effects of age. In calculating z-scores based on norms, a child's performance is compared to that of same-aged peers. When covarying age out of all analyses, adaptive functioning is treated as if it changes consistently according to age. Therefore, covariation does not allow for the possibility that the slope of the line representing the relationship between age and adaptive functioning performance may increase or decrease as a function of age. These changes in the slope could reflect spurts of development in adaptive skills or times of plateau where skills may not improve substantially over time.

The Role of Age at Diagnosis

The third ventricle group was, on average, diagnosed four years later in childhood than the cerebellar group. This is the most salient difference between the two groups, and was confirmed to be the best predictor of group membership allowing for the correct classification 66.7% of cases. This complicates the ability to make comparisons between the two tumor groups and is a serious limitation of this study. Although differences in the predictive power of cognitive measures were found between the two groups, given this tumor location by age at diagnosis interaction it is not possible to determine what might be accounting for the observed differences. This does not appear to be a sampling issue, but rather reflects the typically younger age of diagnosis for children with cerebellar tumors as compared to tumors in other locations. Indeed, infratentorial tumor location has been shown to be more common than supratentorial tumor location in children 3 to 11 years old (Hanif & Shafqat, 2004). This age difference may result not only from location but also from tumor type. There is very little space for a tumor to grow in the cerebellar/posterior fossa area, and as a consequence tumors are likely to become symptomatic much more quickly. Additionally, medulloblastomas, which are typically found in the cerebellum, are most common in young children. This tumor type which accounts for 15-20% of all primary central nervous system neoplasms in children, and more than half of the current sample (10/17), are aggressive. Indeed, only slightly more than half of children diagnosed survive medulloblastomas and their treatment (Eberhart et al., 2002). More severe pathology may be associated with a greater rate of tumor growth and consequently earlier symptom development.

This age difference between the two groups suggests that participants may be fundamentally different when they receive treatment. On average, the third ventricle group members had received four years of formal education, while the cerebellar group members were diagnosed and treatment commenced before the start of first grade. This difference in academic background between the two groups may not only affect short-term functioning, but also may have more pronounced effects over time given the more gradual learning slope children treated for brain tumors tend to display relative to norms (e.g Packer & Mehta, 2002; Palmer et al., 2001). Furthermore this age difference was mirrored at time of testing with ten participants in the cerebellar group under the age of 8, while only 3 participants in the third ventricle group were under the age of 8. Given the narrow age range within the cerebellar group, it is not possible to ascertain how age at diagnosis or testing influences adaptive functioning performance, although the data hints that overall level of functioning and age at evaluation do not appear to be affecting adaptive functioning performance in the cerebellar group. This is in marked contrast to the third ventricle group whose adaptive functioning skills increase the older children are at both diagnosis and evaluation. Within this group there is a strong relationship between academic achievement and adaptive functioning, which is not demonstrated in the cerebellar group.

Should future studies seek to explore adaptive functioning using participants with tumors in these areas it will be important to recruit participants who are diagnosed with tumors across as equivalent an age range as possible in order to remove the confounding effect of age found in this study. If this is not possible, then it would be prudent to compare these tumor locations not to each other, but to other locations with similar mean ages of diagnosis. The lack of any other confounds in this study is somewhat surprising given differences in treatment types favored for the two different locations. Within this study, however, most participants were within three years of brain tumor diagnosis, and it may be that the relationship between these medical and treatment variables and adaptive functioning will become stronger as the amount of time since diagnosis increases.

Cognitive Mediational Models of Adaptive Functioning

Cognitive performance was not shown to mediate the relationship between treatment variables (time since diagnosis, age at diagnosis, chemotherapy, radiation, and hydrocephalus) and overall adaptive functioning performance. The lack of a significant relationship between these treatment variables and adaptive functioning was surprising. It might reflect low power, or possibly that not enough time had elapsed since the initiation of treatment for deleterious effects to become apparent. It would have been desirable to have examined this model separately for each of the tumor groups, however, concerns over sample size precluded this from being done. The above model did not take into account the possibility of cumulative effects of treatment, therefore an exploratory mediational model was tested in which total scores on the Neurological Predictors Scale created by Micklewright et al. (2006) were used. Scores on this scale showed a trend towards a significant relationship with overall adaptive functioning, but were not significantly related to performance on any cognitive measures so testing of this model was discontinued.

Given the pronounced effects radiation is believed to have on cognitive and psychosocial functioning (Dennis et al, 1998; Ellenberg et al., 1987; Fletcher & Copeland, 1988; Moore et al., 1992), an additional exploratory mediational model was tested with the treatment variables of time since radiation and whether radiation treatment was administered. Prior to testing for mediation, the relationship between the radiation variables and cognitive performance was assessed. Time since radiation was significantly related to performance on the PPVT and Trial 1. Full mediation was found for time since radiation. This suggests that the inverse and indirect relationship found between time since initiation of radiation treatment and adaptive functioning skills is due to the decline in cognitive ability, namely in the areas of attention and receptive language/general cognitive ability, as time since radiation increases. This means that increasing the amount of time elapsed since radiation does not directly affect adaptive functioning. Instead, as the amount of time since the initiation of radiation increases, it causes a decline in cognitive performance, and this decline in cognitive performance in turn causes a decline in adaptive functioning performance. This finding confirms the deleterious effects radiation treatment has over time on cognitive functioning, and shows that this resulting cognitive decline affects adaptive functioning performance thereby highlighting both the direct and indirect effects of radiation.

Conclusion

The data used in this study came from a longitudinal study of 191 children diagnosed with brain tumors, however, 36 participants met the inclusion criteria for this study (third ventricle or cerebellar/posterior fossa tumor, RAVLT, PPVT-R, and VABS administered at the same evaluation and within 7 years of diagnosis, and a Composite IQ score above 70). Given our limited number of subjects, there was not always sufficient power for the detection of significant effects, especially within the smaller cerebellar group. This was further exacerbated by the large amount of analyses conducted within the current study. In order to endeavor to combat the potential effects of a small sample, results were discussed in terms of effect size. A further limitation of the current study was its reliance on normative data for the RAVLT compiled from a number of different sources. In light of this short-coming, this study would have benefited from the use of age-matched controls or more comprehensive norms for the RAVLT.

On average, the performance of both groups was within one standard deviation of the mean, suggesting that many participants in both groups are functioning within normal limits relative to same age peers. Nevertheless, more than 25% of the third ventricle group was functioning at our below 1.5 standard deviations from the mean on the VABS Socialization domain as well as the PPVT and RAVLT sum of Trials 1-5 and the Long Delay Free Recall Trial. Within the cerebellar group more than 25% of the sample performed at or below 1.5 standard deviations from the mean on the VABS Communication domain. Studies using other neurological pediatric populations have shown differences in how cognitive performance related to adaptive functioning at different levels of cognitive ability (Liss et al., 2001). It remains unclear how the relationship between these variables might alter in pediatric brain tumor survivors with greater levels of impairment as compared to those functioning within normal limits. It will be important for future studies to examine how both cognitive and adaptive functioning, as well as the relationship between these two constructs, changes over time particularly given the typical decline in performance over time for some individuals in this population. Indeed, within both groups, an increase in time since diagnosis was associated with a decline in adaptive functioning skills relative to same-age peers. Future studies also should explore how cognitive remediation affects adaptive functioning performance in order to determine whether cognitive gains are shown to lead to secondary gains in adaptive functioning.

In spite of these limitations, this study is one of the first to examine the relationship between cognitive abilities and adaptive functioning in children with brain tumors. It has shown that there is a relationship between cognitive and adaptive skills in a pediatric brain tumor sample, and hints that this relationship may vary according to brain tumor location and/or age at diagnosis. It has highlighted the robust role that the PPVT appears to play in predicting adaptive functioning performance for children with tumors of the third ventricle region. Another strength of this study is in its careful analysis of potentially confounding treatment and medical variables.

This study underscores the necessity of further examining how age at tumor diagnosis and age at evaluation may influence the relationship between adaptive functioning and cognitive performance. It also points to the value of exploring differences in the relationship between cognitive measures and adaptive functioning in children with tumors in different regions of the brain, but similar ages of diagnosis, in order to determine whether this relationship also may be influenced by tumor location. This study has highlighted some of the cognitive and treatment factors that relate to adaptive functioning performance, however, given the heterogeneity in treatment and demographic variables as well as cognitive and adaptive functioning post-brain tumor diagnosis it will be important for other studies to confirm and expand upon the results of this study in order to better understand what variables may best predict adaptive functioning performance. In light of the relationship demonstrated between cognitive skills and adaptive functioning, it will be important for future studies to further explore the efficacy of cognitive remediation strategies for both their utility in improving cognitive skills in the pediatric brain tumor population (Butler & Mulhern, 2005) and for their capacity to enhance adaptive functioning skills. Rehabilitation techniques to remediate attention deficits in children treated for cancer have demonstrated clinical utility (Butler 1998; Butler & Copeland, 2002), but whether such an improvement may generalize to adaptive functioning is a question that has yet to be explored.

A comprehensive understanding of adaptive functioning and its correlates as well as of how this relationship may vary according to brain tumor location or age at diagnosis, and change over time in children diagnosed and treated for brain tumors is an important first step in developing techniques to remediate adaptive functioning in this population. With the ultimate goal of improving the quality of life of children with brain tumors, it is hoped that these findings and those of future studies may point to intervention strategies of particular utility in improving adaptive skills and help children with brain tumors achieve an optimal level of independence and quality of life.

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