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The Predictive Contributions of Spatial Planning to Adaptive and Cognitive Functioning in Children Diagnosed with Brain Tumors

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THE PREDICTIVE CONTRIBUTIONS OF SPATIAL PLANNING TO ADAPTIVE AND COGNITIVE FUNCTIONING IN CHILDREN DIAGNOSED WITH BRAIN TUMORS

by

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Under the Direction of Robin D. Morris

ABSTRACT

To date, the effect of planning ability on adaptive functioning has not been extensively examined in children treated for brain tumors. Findings indicate that individuals with brain tumors are more likely to experience poor planning ability (Boyd & Sautter, 1993) and that children with even mild neurological complications demonstrate impairments in adaptive functioning (Fletcher et al., 1990). The purpose of this study is to assess spatial planning and to examine its utility in predicting adaptive and cognitive functional impairment in children diagnosed and treated for brain tumors. Forty children diagnosed with a brain tumor (mean age at diagnosis 8.6 years) were administered the Rey-Osterrieth Complex Figure (ROCF) task, the Vineland Adaptive Behavior Scale (VABS), and the Stanford-Binet Intelligence Scale: Fourth Edition (SB:IV) at an average of one year post diagnosis (post acute) and again at two years post diagnosis (long term). The results of this investigation did not support the use of spatial planning skills as a predictor of adaptive functioning at one year or two years post diagnosis. However, spatial planning skill was an important predictor of cognitive functioning, accounting for a significant amount of variance at both one year and two years post diagnosis. These results were not expected and therefore further analyses were performed in order to better understand the data and results. Additional analyses suggest that it is spatial skill and not spatial planning that predicts adaptive functioning. Further research should continue to ask questions that will impact how we understand executive, adaptive, and cognitive functioning outcomes in children diagnosed with brain tumors.

INDEX WORDS: Adaptive Functioning, Spatial Planning, Cognitive Functioning, Childhood Brain Injury, Brain Tumor

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DEDICATION

In Memoriam

Geneva Ferguson Jackson (Grandmother)

Emma Lee Batts (Grandmother)

Madison Smith (Father-in-Law)

This work is dedicated to my predecessors, those who came before me to make a way for all of us. These great African-Americans worked as educators and completed graduate level work in a time when they were not expected to nor encouraged to succeed. Each of them had strong educational values that they passed along to me and my family. They each believed in me and *if they could only see me now!* I am here because of all of you. Thank you for the sturdy foundation.

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LIST OF ABBREVIATIONS

ADHD	………………………………….Attention Deficit Hyperactivity Disorder
ALL	……………………………………………Acute Lymphoblastic Leukemia
BQSS	……………………………………..Boston Qualitative Scoring System
IQ	…………………………………………………….Intelligence Quotient
PA	……………………………………………………………Pattern Analysis
PNET	…………………………………………Primitive Neuroectodermal Tumor
ROCF	……………………………………………Rey-Osterrieth Complex Figure
SB:IV	…………………………Stanford-Binet Intelligence Scale: Fourth Edition
SES	………………………………………………….Socioeconomic Status
VABS	……………………………………………Vineland Adaptive Behavior Scale

CHAPTER 1: LITERATURE REVIEW

Recent research has reported that individuals with brain tumors are impaired on a variety of tasks that are commonly considered measures of executive function. Executive functions involve planning, selection, and ongoing regulation of behavior (Luria, 1966). While researchers agree that executive functioning plays a significant role in an individual's ability to function independently, little work has examined the relationship between executive functions, particularly planning ability, and everyday adaptive and cognitive functioning in children diagnosed and treated for brain tumors. The purpose of this study is to assess one aspect of executive functioning, spatial planning, and to examine its utility in predicting adaptive and cognitive functioning in children diagnosed with and treated for brain tumors. It is proposed that spatial planning will be significantly associated with adaptive and cognitive functioning, and will enhance our understanding of specific functional impairments beyond that provided by other factors associated with diagnosis and treatment of a brain tumor.

Executive Functioning

Executive functioning has been conceptualized by numerous researchers as a higher order system which orchestrates other mental functions (Cripe, 1996). It includes a number of cognitive abilities, including concept and rule formation, modulation of affective states, planning and organization of goal-directed behavior, response inhibition, and utilization of feedback (Johnson-Greene & Adams, 1998; Kolb & Whishaw, 1996). Lezak (1982) conceptualized executive functions as the ability to formulate goals, make plans, carry out those plans toward meeting desired goals, and effectively perform the activities involved in those plans.

In contrast to elementary operations which are localized to discrete areas of the brain, executive functioning is a more complex function resulting from interconnections among several brain areas (Capone, 1996). Executive functioning falls into Luria's (1973) tertiary zone of cortical functioning. This zone is associative and involves intercommunication between the parietal, temporal, occipital, and prefrontal areas. This zone integrates information from all sensory modalities to perform executive, purposive, and higher-order cognitive functions. Tertiary zones are functional by age 5 - 8 years (Aylward, 1997) although development is not complete until early adulthood (Mrzljak et al., 1990). At two to five years of age, the limited development of the executive system is evidenced behaviorally by impulsivity, disinhibition, egocentrism, here-and-now orientation, and low frustration tolerance (Ylvisaker et al, 1990).

Impact of brain damage on executive functions. The frontal lobes play an important role in executive functioning (Kolb & Whishaw, 1996). In a study investigating lesion localization and cognitive functioning in children of various ages with head injuries, Levin and colleagues (1993) found that measures of executive functioning were most sensitive to the volume of frontal lesions. Neurobehavioral studies of frontal lobe damage strongly support this area's role in social behavior, self-regulation, and executive control processes such as planning, goal formation, flexibility of responding, and delay of responding until an appropriate time (Eslinger, Biddle, & Grattan 1997). Luria (1980) discussed symptoms associated with frontal lobe damage, such as problems in energy, motivation, initiation of actions, formulation of behavioral goals and programs, and behavioral self-monitoring. He viewed the tertiary portions of the frontal lobes as a "superstructure above all other parts of the cerebral cortex, so that they perform a far more universal function of general regulation of behavior than that performed by the posterior associative cortex" (Luria, 1973, pp. 89).

Although the frontal regions make a substantive contribution to executive functioning, other brain regions appear to make significant contributions as well. Functions normally attributed to the prefrontal cortex may be impaired due to structural or functional dysfunction in other areas of the brain. For example, Brouwers, Riccardi, Fedio, and Poplack (1985) posit that given the connections between the caudate and the frontal lobes, calcifications in the basal ganglia (which sometimes occur following cranial radiation) may cause deficits normally seen in patients with frontal lobe abnormalities. Working memory, which has been conceptualized as an aspect of executive functioning (Ylvisaker et al., 1990), is a function of frontal-temporal circuitry (Nestor et al., 1993). Lesions in the temporal region or its connections to the frontal lobe thus have the potential to impair working memory.

Impaired executive functioning has been found in children treated for brain tumors, regardless of radiation treatment. LeBaron, Zeltzer, Zeltzer, Scott, and MacLin (1988) found that 15 children treated for posterior fossa tumors (60% medulloblastoma, 33% astrocytoma, 7% ependymoma) demonstrated higher-level deficits in cognitive flexibility, abstract reasoning, and problem solving regardless of radiation treatment. They hypothesized that higher cortical function may be influenced by compromised lower-level structures via monoamine and other neuroendocrine systems projecting from the brain stem to the forebrain. Another study of children treated for craniopharyngioma (Cavazzuti, Fischer, Welch, Belli, & Winston, 1983) found perseveration and decreased behavioral inhibition, regardless of whether radiation had been included in treatment. A study of the long-term effects of radiation treatment for brain tumors in children under the age of two found these children had poor planning and organizational skills (Spunberg et al., 1981). Children ages four to ten years with prefrontal lesions were found to have problems in organizational ability, shifting response set, self-regulation, and working memory (Eslinger et al., 1997). Although executive functioning is largely impacted by damage to the frontal lobes, deficiencies in higher cognitive abilities also have been observed in children irradiated for cerebellar tumors. Mulhern (1996) proposed that this may be due to fields of radiation therapy encompassing the cerebral hemispheres, as well as the posterior fossa.

One might expect deficits in executive functioning, such as regulation and attentional control, following pre-frontal damage; however, Eslinger and Grattan (1993) stated that executive deficits are not specific to frontal pathology, but also can occur secondary to a disruption to connections that feed into these cerebral regions. In contrast, impairments in planning and organization may occur either as a direct consequence of pre-frontal injury or secondary to an interruption to areas that feed into the frontal lobes and associated deficits in skills such as information processing, visuo-spatial, and visual motor skills (Jacobs & Anderson, 2002).

Planning as a Component of Executive Functioning

Planning is defined as "the identification and organization of the steps and elements needed to carry out an intention or achieve a goal" (Lezak, 1995, pp. 653-654). Das (2002) described planning as the process required when an individual makes decisions about how to solve a problem, carry out an activity, or compose a narrative. Planning involves goal setting, as well as anticipating and monitoring feedback. Mesalum (2000) suggested that the ability to plan and sequence the components of complex activities is essential to normal mental functioning. Planning is most often described in the brain-injured population within the context of other 'executive functions' (Boyd & Sautter, 1993). The ability to plan ahead and solve a problem is considered an integral component of executive functions (Bishop, Aamodt-Leeper, Creswell, McGurk, & Skuse, 2001).

Alexander Luria (1973) conceptualized normal brain functioning as requiring three major units of processing: (1) Attention; (2) Successive and Simultaneous Processing; and (3) Planning. The third unit is of particular importance in this study. Luria conceptualized planning as the process which regulates complex mental activity, such as abstract thought and organization abilities. Luria postulated that all cognitive activities depend upon the cooperation of all three units. When one is not functioning at an optimal level, other cognitive abilities may be compromised (Luria, 1973).

Boyd and Sautter (1993) studied spatial planning, more specifically route-finding, as a measure of everyday executive functioning in adults with head injuries. These researchers developed a spatial planning task based on the theory that understanding deficits in planning will lead to a better understanding of the adaptive or ecological behavior of persons with head injuries.

When defining planning, particularly spatial planning, the concept appears to be fairly abstract. Particularly when applying two-dimensional spatial planning to a three-dimensional space (e.g., map reading and route finding). This type of spatial planning requires one to form a plan “representationally” and then apply it to a novel environment (Sandberg & Huttenlocher, 2001). Sandberg and Huttenlocher (2001) sought to understand the development of advanced spatial skills and advanced planning skills. They found that typically developing children as young as 6-years-old demonstrated advanced spatial planning skills, using maps, by reliably selecting optimally efficient routes. This study highlights the importance of understanding how executive functions develop in children.

Association of Planning and Adaptive Functioning.

As stated earlier, Boyd and Sautter (1993) predicted that understanding deficits in planning would lead to a better understanding of the adaptive or ecological behavior of persons with head injuries. These researchers studied spatial planning as a specific component of executive functions and sought to understand the link between executive and adaptive functioning. Their research sought to evaluate the reliability and validity of a three-dimensional, real-world spatial planning task, the Executive Function Route-Finding Task (EFRT). The EFRT was determined to have high inter-rater reliability and acceptable concurrent validity with other neuropsychological tests. Their findings suggest that understanding planning deficits in an adaptive context contributes valuable information to the field. Deficits in planning have significant functional impact on a child's quality of life, impeding academic progress, and limiting their capacity to maintain appropriate social relationships (Jacobs & Anderson, 2002). Impairments in planning and organization may not be restricted to the domain of executive function, but impact more broadly on cognition and social development, leading to learning and adaptive function difficulties (Eslinger, Biddle, & Grattan, 1997; Marlowe, 1992).

Lezak (1982) stated that "with the executive functions intact, a person can suffer many different kinds and combinations of sensory, motor, and cognitive deficits and still maintain the direction of his own life and be productive as well." When they are impaired, however, there can be major ramifications for a person's adaptive functioning (Yeates & Taylor, 1998). These ramifications may be observed most dramatically in patients with lesions of the prefrontal cortex. These patients tend to experience problems in social behavior, including deficits in speech and other spontaneous behavior (Damasio & Van Hoesen, 1983), apathy (Fuster, 1989), or pseudodepression (Stuss & Benson, 1986) manifested as reduced awareness, lack of initiative, lack of concern, and blunting of emotional responses; and euphoric (Fuster, 1989) or pseudopsychopathic (Stuss & Benson, 1989) symptoms involving sporadic hypomania, disinhibited eating or sexual behavior, and a lack of concern for others. Patients with demonstrated frontal pathology are observed to commonly encounter problems that can be defined as dysexecutive, that is, they are not able to plan and regulate their behavior in an adequate fashion (Fuster, 1989; Lezak, 1995; Luria, 1973; Mesulam, 1985; Shallice 1982; Stuss & Benson, 1983).

Problems with goal directed behavior that interfere with social and vocational functioning are observed frequently by those close to these patients, such as professionals working with them and significant others (Ponsford & Kinsella, 1991). Patients also have reported having difficulties with planning and overseeing their activities, even in daily life situation (Hinkeldey & Corrigan, 1990). In a review of studies of executive function in developmental psychopathologies, Pennington and Ozonoff (1996) found that early lesions to the prefrontal cortex result in executive function deficits and conduct-disordered behavior.

Delayed effects of prefrontal lesions also may be observed both for cognitive processes, particularly executive functions, and for social cognition and behavior (Eslinger, Grattan, & Geder, 1995). They may appear to worsen with time as a result of a widening discrepancy between expected and actual development of prefrontal functions (Eslinger et al., 1997). This disparity may be particularly evident in adolescence. These deficits may affect adversely an individual's adaptation throughout the lifespan, more so than intellectual and sensorimotor deficits. These individuals may experience difficulties such as an inability to develop or sustain meaningful friendships or family relationships over time. Eslinger et al. (1997) reviewed eight cases of childhood prefrontal lesions, with age at time of assessment ranging from birth to 16 years. Despite age of onset and specific area of the lesion within the prefrontal cortex, all cases had significant alterations in social development or behavior in spite of generally preserved intellect, language, perception, and memory.

The relationship between impaired executive and social-emotional functioning has been conceptualized by Rourke and Fuerst (1991) as a type of nonverbal learning disability (NLD). Their model posits that deficits in adaptation to novel and complex situations, social perception and judgment, and social interaction skills, combined with poor pragmatic language skills, place a child at risk for the development of socio-emotional problems. Rourke (1989) also has proposed that these deficits stem from lesions in the white matter which carries information to the right hemisphere. Rourke has predicted that the NLD syndrome should be evident in children with brain tumors who have been treated with cranial radiation because white matter is very sensitive to the effects of radiation and there is a greater ratio of white matter to gray matter and a greater representation of association areas in the right hemisphere as compared with the left (Goldberg & Costa, 1981).

Buono and her colleagues (1998) investigated the utility of Rourke's (1989) NLD model in characterizing the functioning of children treated with brain tumors. When comparing 123 children treated for brain tumors who had relative weaknesses in arithmetic as compared with reading on the WRAT, children with arithmetic deficits had a trend (although not statistically significant) toward higher incidence of impairment in executive functioning and adaptive behavior. The authors stated that their measure of executive functioning (Trails Part B) may have not been adequate to assess all of the complex abilities associated with this domain.

The relationships between adaptive functioning and individual variables (e.g., demographic, medical, executive functioning) are probably more complex than the previous findings suggest. Papero, Prigatano, Snyder and Johnson (1993) examined adaptive functioning in 86 children with closed head injuries 1-3 years after hospitalization. Patients were classified as having either severe, moderate, or mild head injuries. Findings suggest that moderate to severe head injuries in boys may be associated with long-term disruptions in adaptive functioning, greater than one would expect based on their IQ. Vineland Adaptive Behavior Scale (VABS) scores for boys were reported to be at least one standard deviation below the mean for IQ. Specific deficits were observed in the areas of socialization and communication. The results appear to be confounded with gender. Girls with moderate to severe head injuries displayed no overall deficits in adaptive behavior. Younger boys showed the greatest deficits in adaptive behavior. The investigators speculate that the observed gender effects may reflect cultural differences in parental expectations for boys and girls. Additionally, such differences may be intensified following a traumatic event such as a head injury. In general, the findings are consistent with other studies that have found that the majority of children with head injuries, even mild, show some impairments in adaptive behavior and social competence up to 3 to 4 years post trauma (Costeff, Groswasser, Landman, & Brenner, 1985; Fletcher et al., 1990; Perrott, Taylor, & Montes, 1991). Difficulties can include problems with interpersonal relationships, social contacts, leisure interests and functional independence (Levine, Van Horn, & Curtis, 1993). An attempt to understand these difficulties in children with brain injuries has led to research on various factors which may contribute to adaptive and cognitive functional problems.

<u>Other Factors Which May Contribute to Functional Difficulties</u>

Studies have shown a link between several other demographic, medical factors and functional outcome in children with brain tumors. These controlled studies have explored the contributions of pre-treatment, treatment, and post-treatment variables in the development of cognitive deficits (Glauser & Packer, 1991). These factors include age at diagnosis/treatment, tumor location and type, and treatment type. Additionally, socioeconomic status (SES) also has been implicated in functional outcome.

Age at diagnosis and treatment has been implicated as a critical factor in the cognitive outcome of children treated for brain tumors (Fletcher & Copeland, 1988; Mulhern, Hancock, Fairclough, & Kun, 1992; Ris & Noll, 1994). In general, studies have shown that children diagnosed under the age of 6 are at an increased risk for long-term cognitive impairments especially if treated with whole brain radiation therapy (WBRT).

Mulhern, Crisco, and Kun (1983) reviewed 15 studies of brain tumor survivors. They concluded that children treated for brain tumors at a young age show a greater incidence of intellectual impairment when compared to children treated at an older age. Kun and Mulhern (1983) conducted a series of evaluations with 18 children following radiation treatment for brain tumors. The median time since treatment was 22 months at the time of the first evaluation, 41 months at the second evaluation, and 49 months at the third evaluation. Although no significant correlations between age and IQ were found within the first evaluation, it was reported that intellectual delays were observed in 50% of the children less than 6 years of age at initial evaluation. At the second evaluation, no significant decline in IQ scores was observed; however, 56% of those less than 6 years old showed a decline in memory function, compared to only 11% of the older children. It is unclear if this group difference is significant because it does not appear that any statistical analyses were performed due to the small sample size.

Tumor location and type also have been investigated for their effects on outcome (Gauser & Packer, 1991; Mulhern, Crisco, & Kun, 1983). Attempts have been made to determine the differential effects of tumor location. In Ris and Noll's (1994) review, they noted that most studies contain samples that include various tumor types located in different brain areas. This is largely due to the relatively low incidence rate of pediatric brain tumors in the general population. Tumors with extension to the hypothalamus (Danoff et al., 1982) and tumors involving the brainstem (Hirsch, et al., 1979) have been found related to below average intellectual outcomes.

Tumor type also has been implicated to effect intellectual outcomes. Following treatment, it appears that those with supratentorial tumors are at greater risk for intellectual deficits compared to those with infratentorial tumors (Mulhern, 1996; Mulhern & Kun, 1985; Ris & Noll, 1994). However, at least one study reported that the opposite was true for those less than 6 years of age at the time of diagnosis (Mulhern & Kun, 1985). However, it should be noted, that this finding may be due more to treatment effects than tumor type or an interaction of the two. Supratentorial hemispheric tumors are generally well-circumscribed and total or near – total surgical resection is possible along with post-operative irradiation and/or chemotherapy. Supratentorial midline tumors, on the other hand, usually require focal irradiation as the primary treatment due to their location. Further, infratentorial tumors generally involve posterior fossa craniotomy as well as WBRT and/or chemotherapy (Albright, 1993).

Treatment type is one of the more widely studied variables hypothesized to affect outcome. There are three primary methods of treatment for brain tumors: (1) surgical resection, (2) chemotherapy, and (3) radiation therapy (Finlay, Uteg, Giese, 1987). Wile-Bordeaux and colleagues (1988) studied the acute (one year post-treatment) effects of surgical and central nervous system (CNS) irradiation treatments for childhood brain tumors and found no significant pre- versus post-therapy neuropsychological changes for either group. However, the majority of studies have found that the performance of children who have received irradiation to deteriorate after treatment (e.g. Copeland et al., 1985; Duffner, Cohen, & Parker, 1988; Duffner, Cohen, & Tomas, 1983; Ellenberg, McComb, Siegel, & Stowe, 1987; Glauser & Packer, 1991; Hirsch et al., 1979; Mulhern, Crisco, & Kun, 1983; Ris & Noll, 1994; Roman & Sperduto, 1995). Additionally, the synergistic effect of multiple treatments has been identified as a primary etiologic factor in children with cognitive sequelae (Gamis & Nesbit, 1991).

Socioeconomic status (SES) also has the potential to impact outcome in children treated for brain tumors. However, little is known about the impact of low SES on the cognitive and adaptive functioning of children treated for brain tumors. In general, children from lower SES backgrounds tend to score lower on IQ tests (Prifitera, Weiss, & Saklofske, 1998). While it is consistently found in the general mental health literature that lower SES is associated with an increased rate of adjustment difficulties, the contribution of SES to the adjustment of children with a chronic illness is not fully understood (Thompson & Gustafson, 1996).

Pediatric Brain Tumors

Children diagnosed with and treated for brain tumors are a unique group compared to children who survive other cancers because of the direct involvement of the tumor on critical brain structures (Kullgren, 1996). Cancer accounted for 10% of all childhood deaths in 1991 (Wingo, Tong, & Bolden, 1995) and is the most common cause of disease-related mortality for children aged 1 to 19 years in the United States (Reis, 1999). Brain tumors and other CNS cancers make up approximately 17% of childhood malignancies and are second only to leukemia in cause of death among childhood cancers (Linet et al., 1999; Wingo et al., 1995). In the US, invasive CNS cancers are diagnosed in approximately 2,200 children under the age of 20 years annually (Gurney, Smith, & Bunin, 1999). The incidence rates for children have increased over the past two 20 years. Males had a higher incidence rate relative to females (24% higher) as did white children relative to black children (18% higher). The reason for this is not clear (Gurney, Smith, & Bunin, 1999). Astrocytomas account for 52% of all CNS malignancies, followed by primitive neuroectodermal (PNET) which comprises 21%. Other gliomas make up 15% of all CNS malignancies and ependymomas account for an additional 9% (Gurney, Smith, & Bunin, 1999). There has been no consistent information to date concerning the risk factors associated with acquiring a brain tumor. Sex, therapeutic doses of ionizing radiation to the head, and certain hereditary conditions are clearly associated with increased susceptibility to CNS cancer in children (Gurney, Smith, & Bunin, 1999).

Attempts to identify factors that place children at risk for functional difficulties following diagnosis and treatment for brain tumors has resulted in conflicting findings. Age at diagnosis, tumor type and site, treatment modality, and degree of cosmetic and functional disability all have been implicated; however, there is little consistency in the findings (Carpentieri, Mulhern, Douglas, Hanna, & Fairclough, 1993; Mulhern, Wasserman, Fairclough, & Freidman, 1989). Research has shown that a younger age at diagnosis for a brain tumor negatively impacts cognitive outcome (Ellenberg, McComb, Siegel, & Stowe, 1987; Ris & Noll, 1994).

CHAPTER 2: INTRODUCTION

Executive dysfunction, in particular poor planning ability, as a consequence of the occurrence of, and treatment for a brain tumor may impact adaptive functioning. Examination of the literature on adaptive functioning in children indicates that adaptive behavior is a multi-determined and modifiable function (Cicchetti & Sparrow, 1990). A child's level of adaptive functioning can be considered as an interaction of several individual biological and environmental factors. To date, the effect of planning ability on adaptive functioning has not been examined extensively in children treated for brain tumors. Findings indicate that individuals with brain tumors are more likely to experience poor planning ability (Boyd & Sautter, 1993). Findings also indicate that even children with mild neurological complications demonstrate impairments in adaptive functioning (Costeff, Groswasser, Landman, & Brenner, 1985; Fletcher et al., 1990; Perrott et al., 1991).

Several studies also have suggested that adaptive behavior has significant diagnostic value in certain child populations when examined with neurocognitive functioning (Cicchetti & Sparrow, 1990; Sparrow & Cicchetti, 1989). These studies have primarily examined children with developmental or psychiatric disorders. In such populations, intelligence and adaptive behavior are moderately correlated, suggesting that differences may be clinically meaningful. Discrepancies between intelligence and adaptive behavior are found to significantly discriminate between children, for example with autism and mental retardation (Volkmar, Carter, Sparrow, & Cicchetti, 1993).

This study, therefore, was designed to examine the relationship between planning ability and functional ability (adaptive and cognitive functioning) in children with brain tumors. The purpose of this study was to evaluate the potential impact of spatial planning skill deficits on day-to-day functional development in a pediatric population and their long-term functional ability. Spatial planning was assessed using a complex visual-spatial planning task, the Rey-Osterrieth Complex Figure (ROCF) task, adaptive functional ability was assessed by the Vineland Adaptive Behavior Scale (VABS), and cognitive ability was assessed by the Stanford-Binet Intelligence Scale: Fourth Edition (SB:IV). The following hypotheses were considered:

1. Spatial planning ability at one-year post diagnosis (post-acute phase) or two-years post diagnosis (long term) will predict functional ability (adaptive and cognitive ability) at concurrent time points.
2. Spatial planning ability in the post-acute phase of recovery will predict long-term adaptive and cognitive functional ability and have predictive efficacy beyond demographic and medical factors. Spatial planning ability at one-year post diagnosis will predict functional ability at two-years post diagnosis better than SES and number of treatments.

CHAPTER 3: METHOD

Participants

Data for this study were drawn from a longitudinal research project designed to assess the effects of brain tumors and their treatment on aspects of child and family functioning. The participants were recruited from pediatric medical centers in a large urban city. Extensive intellectual, academic, neuropsychological, and psychological testing were conducted with each child at specific intervals, as possible, as follows: (1) at diagnosis when possible; (2) six months from diagnosis, and (3) on each anniversary of the diagnosis until the child achieved age 18. At each interval, the parents also completed measures to evaluate child and family functioning. The number of evaluations conducted for each child ranged from 1 to 11 (M = 3.7, SD = 2.6). Informed consent was obtained from all participating families.

A total of 40 children ages 6 to 16, diagnosed with brain tumors were selected for the present study from a total 191 children whose parents originally signed consent for the study. Children were not included in this study if they were younger than 6 years of age at the time of assessment (n = 63), or if they were not given all the necessary measures on at least two separate occasions within the time frame of the study (n = 88). Twenty-eight children died during the study. Participants for the present study also were selected based on the criteria that they had been evaluated with the Rey-Osterrieth Complex Figure (ROCF), the Stanford-Binet Intelligence Scale – 4^{th} edition (SB:IV), and the Vineland Adaptive Behavior Scale (VABS) at an average of one year post-diagnosis (Table 1) and again at an average of two years post-diagnosis (Table 1). This will allow for comparison of findings over time. Descriptive statistics for demographic data are presented Table 2.

Table 1

Description of Time Points of Evaluation

	X	SD	Range
Months Since Diagnosis (One Year Post-Diagnosis)	13.48	3.55	6-24
Months Since Diagnosis (Two Years Post-Diagnosis)	25.95	4.08	22-38

Table 2

Demographic and Medical Characteristics for the Total Sample and the Study Sample

	Total Sample (N=191)	**Study Sample (n=40)**
Sex	45.5% Female	41.9% Female
Race	26.0% Non-Caucasian	27.9% Non-Caucasian
SES	3.1 (SD = 1.18, Range 1.0-5.0)	3.0 (SD = 1.18, Range 1.0-5.0)
Age at Diagnosis	7.4 (SD = 4.6)	8.6 (SD = 3.5)
Tumor Pathology		
Glioma/Astrocytoma	50.8%	45.0%
PNET	30.8%	27.5%
Other	18.4%	27.5%
Tumor Location	66.5% Non-Cortical Lesions	57.5% Non-Cortical Lesions
Number of Treatments		
Multiple	70.0%	67.5%
Single or No Treatment	30.0%	32.5%

Note. [a] SES = Socioeconomic Status on a scale of 1 (high) to 5 (low) (Hollingshead, 1957)
[b] PNET = Primitive Neuroectodermal Tumor

Medical Characteristics. Tumor pathology distribution in this sample is similar to previous reports of the prevalence of brain tumor diagnoses in children (Black, 1991). Consistent with national incidence rates of childhood brain tumors (Gurney, Smith, & Bunin, 1999), glioma/astrocytoma was the most frequently diagnosed tumor, followed by primitive neuroectodermal tumors (PNETs), and other types of tumors. Medical data also was presented in Table 2. Previous research has documented a relationship between multiple treatments for brain tumors and poorer intellectual and achievement outcomes two to four years post-diagnosis (Carlson-Green, Morris, & Krawiecki, 1995; Moon, 1995). In order to address this phenomenon, the number of treatments following diagnosis will be classified into two categories, one comprised of children who had multiple treatments in variable combinations (surgery/radiation, surgery/chemotherapy, radiation/chemotherapy, or all three treatments). A second category was comprised of those children who had a single treatment or no treatment at all.

Measures

Predictor measure. The Rey-Osterrieth Complex Figure (ROCF) was used to assess planning and organization ability. The ROCF has been utilized in studies of children and adults to assess some components of executive function and planning (Eslinger & Gratten, 1990; Grossman et al., 1993; Schreiber, Javorsky, Robinson, & Stern, 1999). Developed by Andre Rey in 1941 for the evaluation of adults with brain damage, the ROCF consists of a central rectangle, bisecting lines, and a variety of internal and external details. The ROCF originally was designed to assess visual perceptual ability and visual memory, but also requires the ability to plan and organize complex materials (Corwin & Bylsma, 1993; Lezak, 1983; Osterrieth, 1944; Rey, 1941). Patients with frontal lobe damage have been found to make more perseverations and omissions and use a more disorganized approach when copying this figure (Messerli, Seron, & Tissot, 1979; Pillon, 1981).

Waber and colleagues (1994) used the ROCF to explore executive function deficits in a group of long-term survivors of childhood acute lymphoblastic leukemia (ALL). Survivors have been shown to exhibit increased difficulty with visuospatial reasoning tasks. The study was undertaken to determine whether this difficulty reflects underlying spatial and visuoperceptual deficits or has a basis in executive dysfunction. The ROCF was given under both standard and structured procedures. During the structured administration, participants were instructed to copy the figure by following either a configural (one identifiable part at a time) or linear (left to right) approach. Participants given the configural approach performed substantially better on a recall condition than those who used the left to right structured format or the standard condition. Waber and colleagues (1994) argued that the poor performance of these participants on visuospatial tasks reflects deficits in effective deployment of attention, planning, and strategy development rather than a visual perceptual or spatial deficit.

Another study used ROCF to examine similar deficits in children with ADHD. Cahn and Marcotte (1995) demonstrated that children with ADHD were able to recall less information on the immediate recall portion of the ROCF than normal controls. However, participants with ADHD were able to retain an average of 93% of the original information recalled after a significant delay which suggests that initial learning may be affected by the difficulty with sustained attention and organization found in children with ADHD.

Inconsistent results have been obtained in several studies using the ROCF which have been attributed to scoring systems which focus on the completed product as opposed to the process used by the individual to copy the figure (Reader et al., 1994). Administration of the

ROCF allows for a qualitative evaluation of the participant's performance; however, the Osterrieth scoring system only allows for quantitative evaluation of the participant's production of the figure. Drawings are scored based on the presence and accuracy of individual units with each unit of the figure considered to be of equal importance. A scoring system developed by Waber and Holmes (1985) attempted to capture better some of the qualitative aspects of performance on the ROCF in order to assess developmental changes in children's productions. The system was designed to assess four parameters objectively: organization, style, accuracy, and errors.

In another attempt to assess the many qualitative and planning aspects of ROCF productions, Stern et al. (1994) developed the Boston Qualitative Scoring System (BQSS). The BQSS was designed to capture the organizational aspects of the ROCF. The system divides the figure into three sets of component parts believed to be hierarchical in importance (Configural Elements, Clusters, and Details) and judges the drawing on 17 different dimensions. The BQSS is useful in assessing specific qualitative aspects of the production (e.g., planning) as well as its overall organization, and has been shown to possess adequate interrater reliability (Stern et al., 1994). The BQSS Planning score is designed to assess qualitatively the overall organization of the production, including the approach used to break down the figure. The criteria are based on the importance of preserving the integrity of the rectangle. Higher scores are given for drawing the rectangle and the main features of the figure first, and variations from this receive lower scores.

For the purpose of this study, the BQSS Planning score was used to determine spatial-planning ability. The BQSS Planning score yields a score from 0 (which is no planning ability evidenced) to 4 which is perfect planning ability. Almost half of the participants scored a 0, leaving a very small number in the other categories of planning (1-4). Therefore, the participants were categorized as either a 0 (no planning ability) or a 1 (some planning ability) based on their BQSS Planning scores.

Outcome measures. The Stanford-Binet Intelligence Scale- 4th edition (SB:IV; Thorndike, Hagen, & Sattler, 1986) is an individually administered test which yields a composite standard score based on the child's age. This composite score is considered an overall score of intellectual functioning. The SB:IV is divided into four factors which yield four area scores: verbal reasoning, quantitative reasoning, abstract/visual reasoning, and short-term memory. Specific subtests are assigned within each area. There are a total of 15 subtests on the SB:IV; however, only six are given at every age (Vocabulary, Comprehension, Pattern Analysis, Quantitative, Bead Memory, and Memory for Sentences), and these were used in the present study.

The Composite Score of the SB:IV has an internal consistency reliability coefficient that ranges from r_{xx} = .95 to .99 over the 17 age groups (Sattler, 2002b). The median Composite Score reliability is r_{xx} = .97. The SB:IV has been deemed a valid measure of intelligence (Lamp & Krohn, 2001; Sattler, 2002b). In studies of the criterion validity of the SB:IV Composite score, the SB:IV correlated well with the Wechsler Intelligence Scale for Children – 3rd Edition (r = .81) and with the Peabody Individual Achievement Test (r = .86; Sattler, 2002b).

The Vineland Adaptive Behavior Scales – Survey Form (VABS; Sparrow, Balla, & Cicchetti, 1984) is a measure of personal and social skills. It is based on a definition of adaptive behavior as the ability of the individual to perform daily activities required for personal and social sufficiency (Sattler, 2002a). The VABS measures adaptive behavior in four domains (Communication, Daily Living Skills, Socialization, and Motor Skills) and these domains are combined to form an Adaptive Behavior Composite. The VABS is administered as an interview with an informant who is familiar with the child's behavior, usually a parent. Items are scored on a 0 to 2 point scale where 0 = no, never, 1 = sometimes, partially, and 2 = yes, usually. Items also can receive an N for no opportunity or DK for don't know. Raw scores are converted to standard scores (*M* =100, *SD* = 15) for the four adaptive behavior domains and for the Adaptive Behavior Composite.

Median internal consistency reliabilities range from .83 to .95 for the four factors and .94 to .98 for the composite (Sattler, 2002a). The manual reports that the VABS has acceptable validity. It is stated that the raw scores increase with age, a factor analysis generally supports the four domains, and the forms have satisfactory correlations with other measures of adaptive behavior. The VABS was used in this study as a measure of adaptive functioning.

Several studies indicate that children with brain tumors and/or treated with cranial irradiation therapy are at increased risk for neuropsychological and behavioral difficulties (Butler & Copeland, 2002; Mulhern, Wasserman, Friedman, & Fairclough, 1989; Ris & Noll, 1994). Butler and Copeland (2002) suggest that children treated with cranial irradiation may demonstrate significant impairments in adaptive functioning. This is supported by two studies investigating adaptive functioning (specifically using the Vineland) in children treated with cranial irradiation for brain tumors (Horowitz et al., 1988; Packer et al., 1987). The authors reported adaptive behavior scores that ranged from low average to deficient. Another study by Carlson-Green, Morris, and Krawiecki (1995) reported below average levels of adaptive behavior for children with brain tumors and no significant difference between those treated with cranial irradiation and without. It also was noted in this study that higher adaptive functioning was related to a higher level of SES, shorter time since diagnosis, and less reliance on coping strategies by mothers.

CHAPTER 4: RESULTS

Data Analyses

All data were analyzed with SPSS version 12.0 for Windows® (2004). Prior to analyses, all variables were examined for accuracy of data entry, missing values, and outliers. Outliers on the dependent variables were defined as those values greater than or less than 3 standard deviations from the mean. There were no outlying scores or missing values for the dependent variables.

Given the stability of many of the measures from one year post diagnosis to two years post diagnosis the sample was further explored. Four subgroups emerged when looking at the stability of planning scores over the two time points. Table 3 summarizes the background and medical factors of the sample. Group 1 consisted of 19 participants whose planning scores were stable at zero (0). Group 2 consisted of 7 participants whose planning scores were stable and greater than zero. Group 3 consisted of 7 participants whose scores got better from one year post diagnosis to two years post diagnosis. Finally, Group 4 consisted of 7 participants whose scores declined from one year post diagnosis to two years post diagnosis.

Description of Spatial Planning Ability and Adaptive and Cognitive Functioning

Figure 1 displays descriptive information about how the participants performed on the ROCF task. Additional information on percentile rankings for the copied figure is presented in Figure 2.

Mean adaptive functioning as measured by the Vineland Adaptive Behavior Scale (VABS) fell in the average range (Table 4) at one year post diagnosis and two years post diagnosis, yet differed significantly from the normative sample (1 year post: $t(39) = -2.83$, $p<.01$; 2 years post: $t(39) = -3.45$, $p<.01$). Scores on the VABS Composite ranged from very low to high levels of adaptive abilities and were correlated significantly over the two time points ($r = .80$, $p<.001$). Mean cognitive performance fell within the average range (Table 4) and within expected limits when compared to the normative sample (1 year post: $t(39) = -1.19$; 2 years post: $t(39) = -1.16$). Cognitive performance also was significantly correlated over the two time points ($r = .86$, $p<.001$)

Correlations Among Outcome Measures and Potential Predictor Variables

Table 5 presents the correlations among the outcome measures and potential predictor variables. Correlations between adaptive and cognitive performance were moderate and significant. Weaker, yet significant, relations were found among planning and adaptive functioning, and planning and cognitive functioning. There was no significant correlation among SES, number of treatments, and planning ability.

Testing of Hypotheses

Linear regressions were used to examine the relationship between planning ability and functional ability (adaptive and cognitive functioning) in children with brain tumors. More specifically, analyses were performed to evaluate the potential impact of spatial planning skill deficits on day-to-day functional development in a pediatric population and their long-term functional ability. Background and medical variables were entered in the first block and the spatial planning score was entered in a second block to determine which proportion of the variance was accounted for over and above the demographic and medical factors.

Within the demographic domain, SES was chosen because of the consistent finding in the general psychology literature that lower SES is associated with poorer cognitive and psychosocial outcomes (McLoyd, 1998). With respect to illness factors, previous research has documented a relationship between multiple treatments for brain tumors and poorer intellectual and achievement outcomes two to four years post-diagnosis (Carlson-Green, Morris, & Krawiecki, 1995; Moon, 1995). For the purpose of this study, the number of treatments following diagnosis was classified into two categories, one comprising of children who had multiple treatments in variable combinations (surgery/radiation, surgery/chemotherapy, radiation/chemotherapy, or all three treatments), and a second category made up of those children who had a single or no treatment at all.

Hypothesis 1a. It was predicted that spatial planning ability at one-year post diagnosis would predict adaptive functional ability at the same time point. As reported in Table 6, SES and number of treatments accounted for 28% of the variance in adaptive functioning at one year post-diagnosis. Taking SES and number of treatments into account, spatial planning (1 year post) uniquely accounted for 7% of additional variance. The final equation approached significance and accounted for 35% of the variance in adaptive functioning at one year post-diagnosis in this sample.

Hypothesis 1b. It was predicted that spatial planning ability at one year post-diagnosis would predict cognitive functional ability at that same time point. As reported in Table 6, SES and number of treatments accounted for 31% of the variance in cognitive ability (IQ Composite) at one year post-diagnosis. Taking SES and number of treatments into account, spatial planning (1 year post) uniquely and significantly accounted for 19% of additional variance. The final equation was significant and accounted for 50% of the variance in IQ Composite (1 year post) in this sample.

Hypothesis 1c. It was predicted that spatial planning ability at two years post-diagnosis would predict adaptive functional ability at that same time point. As reported in Table 6, SES and number of treatments accounted for 17% of the variance in adaptive functioning (2 years post). Taking SES and number of treatments into account, spatial planning (2 years post) uniquely accounted for less than 1% of additional variance. The final equation was not significant and accounted for 18% of the variance in adaptive functioning at two years post-diagnosis in the sample.

Hypothesis 1d. It was predicted that spatial planning ability at two years post-diagnosis would predict cognitive functional ability (IQ Composite) at that same time point. As reported in Table 6, SES and number of treatments accounted for 22% of the variance in IQ composite at two years post-diagnosis. Taking SES and number of treatments into account, spatial planning ability (2 years post) uniquely and significantly accounted for an additional 10% of the variance. The final equation was significant and accounted for 32% of the variance in IQ composite (2 years post) in this sample.

Hypothesis 2. Spatial planning ability at one year post diagnosis was hypothesized to predict adaptive and cognitive functional ability at two years post diagnosis and have predictive efficacy beyond demographic and medical factors. Taking SES and number of treatments into account, spatial planning ability (1 year post) uniquely accounted for an additional 3% of the variance in adaptive functioning (2 years post). The final equation was not significant and accounted for 20% of the variance in adaptive functioning at two years post-diagnosis (Table 7). In addition, spatial planning ability at one year post-diagnosis uniquely and significantly accounted for an additional 12% of the variance in IQ composite at two years post diagnosis. The final equation was significant and accounted for 23% of the variance in cognitive functioning at two years post-diagnosis (Table 7).

Post Hoc Analyses

In an effort to better understand the results, post hoc analyses were performed. A closer look at medical and background factors revealed a significant correlation between age at diagnosis and spatial planning and age at diagnosis and percentile ranking on the ROCF at both one year and two years post-diagnosis (Table 5). In this sample, number of treatments was not significant; therefore, age at diagnosis was used as a medical background factor in its place for additional post hoc analyses.

Additionally, tumor pathology was studied in relation to the outcome variables. The number of participants falling into the tumor pathology categories of glioma/astrocytoma, PNET, or other as a function of their VABS Composite performance at one year post diagnosis is shown in Figure 3. VABS Composite scores were grouped for a clearer understanding of the data. Those scores that fell below a standard score of 80 were classified as low, standard scores between 81 and 110 were classified as average, and scores above 110 were classified as high. Although participants with a PNET tumor performed slightly worse than those with different tumor categories, the difference is not significant, X^2 (6, 40) = 4.54. Similar results were found for VABS Composite at two years post diagnosis, X^2 (4, 40) = 2.22 (see Figure 4). Crosstabulation results of tumor pathology as a function of the participants SB:IV Composite performance at one year and two years post diagnosis is show in Figures 5 and 6 respectively. These scores were classified in the same manner as the VABS composite scores. These scores also were not significant (one year post: X^2 (4, 40) = 5.12; two years post: X^2 (4, 40) = 8.73.

Table 8 presents correlations among tumor pathology and potential predictor variables. There were no significant correlations between tumor pathology and ROCF planning, ROCF percentile ranking, or SB:IV Pattern Analysis scores.

The VABS and the SB:IV each have subscales that combine to make the composite score. Exploration of those subscales yielded some significant correlations between the subscales and the ROCF task. In particular, the percentile rankings at one year post diagnosis were significantly correlated with the Communication (r = .62) subscales of the VABS and the Verbal (r = .43), Visual (r = .68), and Short Term Memory (r = .42) subscales of the SB:IV at the concurrent time point. The planning score on the ROCF was significantly correlated with the Communication (r = .34) subscales of the VABS and the Verbal (r = .33), Visual (r = .55), and Short Term Memory (r = .41) subscales of the SB:IV at the concurrent time point. At two years post diagnosis, the percentile rankings did not significantly correlate with any of the subscales of the VABS and was significantly correlated with the Verbal (r = .51), Visual (r = .66), Quantitative (r = .50), and Short Term Memory (r = .58) subscales of the SB:IV at the concurrent time point. The planning score at two years post diagnosis was not significantly correlated with any subscales of the VABS and was significantly correlated with the Visual (r = .46) subscale of the SB:IV at the concurrent time point. When examining scores from one year post diagnosis to two years post diagnosis, the percentile rankings were significantly correlated with all of the subscales of the VABS and the SB:IV (Table 8). The planning score was significantly correlated with all of the subscales of the SB:IV (Table 8).

In order to explore the stability of the subscales over the two time points *t*-tests were performed. On the VABS, the Communication and Socialization subscales appeared to remain fairly stable as there was no significant difference between the two time points ($t(39) = .29$, $p =$

.77; *t*(39) = 1.40, *p* = .17, respectively). There was a significant decline in score on the Daily Living Skills subscale of the VABS (*t*(39) = 2.37, *p*<.05). The SB:IV appears stable on all subscales as there was no significant difference between the two time points (Table 9).

The Pattern Analysis (PA) subtest of the SB:IV was analyzed to determine if spatial skills were more predictive of adaptive and cognitive functioning than spatial planning. The PA subtest significantly correlates with ROCF planning score and percentile rankings at all time points (Table 10) and the PA subtest is relatively stable over the two time points (*t*(39) = .33, *p*=.74).

Different regression equations were established given the new information regarding medical/background factors, subscales, and the PA subtest. To further understand the contribution of spatial skills versus that of spatial planning, spatial skills (PA) were used to predict adaptive and cognitive ability at concurrent time points as well as at two separate time points (one year post diagnosis and two years post diagnosis). As reported in Table 11, SES and age at diagnosis accounted for 26% of the variance in adaptive functioning at one year post-diagnosis. Taking SES and age at diagnosis into account, spatial ability (PA, 1 year post) uniquely accounted for 9% of additional variance. The final equation was significant and accounted for 35% of the variance in adaptive functioning at one year post diagnosis. As reported in Table 11, SES and age at diagnosis accounted for 38% of the variance in cognitive functioning at one year post-diagnosis. Taking SES and age at diagnosis into account, spatial ability (1 year post) uniquely accounted for an additional 33% of variance. The final equation was significant and accounted for 71% of the variance in cognitive functioning at one year post diagnosis. Table 11 also reports information regarding adaptive and cognitive ability at two years post diagnosis. SES and age at diagnosis accounted for 15% of the variance in adaptive functioning at two years post diagnosis. Taking SES and age at diagnosis into account, spatial ability (2 years post) accounted for 23% of additional variance. The final equation was significant and accounted for 38% of the variance in adaptive functioning at two years post diagnosis. With regard to cognitive functioning at two years post diagnosis, SES and age at diagnosis accounted for 32% of the variance and spatial ability accounted for 40% of additional variance. The final equation was significant and accounted for 72% of the total variance in cognitive ability at two years post diagnosis.

An additional regression was run to determine if spatial ability at one year post diagnosis would predict adaptive and cognitive functioning at two years post diagnosis better than SES and age at diagnosis. As reported in Table 12, SES and age at diagnosis accounted for 15% of the variance in adaptive functioning at two years post diagnosis. Taking SES and age at diagnosis into account, spatial ability at one year post diagnosis accounted for an additional 8% of the variance in adaptive functioning at two years post diagnosis. The final equation approached significance and accounted for 23% of the total variance. Table 12 also reports that SES and age at diagnosis accounted for 32% of the variance in cognitive ability at two years post diagnosis. Taking SES and age at diagnosis into account, spatial ability at one year post diagnosis accounted for an additional 22% of the variance in cognitive ability at two years post diagnosis and the final equation was significant and accounted for 54 % of the total variance in cognitive functioning at two years post diagnosis.

The percentile rankings of the ROCF task at one year post diagnosis was found to account for 9% of the variance in adaptive functioning (1 year post), when SES and age at diagnosis was taken into account (26% of the variance). The final equation was significant and accounted for 35% of the total variance in adaptive functioning at the concurrent time point

(Table 13). Percentile rankings of the ROCF at one year post diagnosis accounted for an additional 9% of the variance in cognitive functioning (1 year post), when SES and age at diagnosis was taken into account (38% of the variance). The final equation was significant and accounted for 47% of the total variance in cognitive functioning (1 year post; Table 13). As reported in Table 13, percentile rankings of the ROCF at two years post diagnosis accounted for an additional 8% of the variance in adaptive functioning (two years post) when SES and age at diagnosis were taken into account (15% of the variance) and the final equation was not significant, accounting for 23% of the total variance. Table 13 also indicates that percentile rankings of the ROCF at two years post diagnosis accounts for an additional 18% of the variance in cognitive functioning (2 years post) after SES and age at diagnosis are considered (32% of the variance). The final equation was significant and accounted for 50% of the total variance in cognitive functioning at the concurrent time point.

An additional analysis was run to determine if percentile rankings at one year post diagnosis would predict adaptive and cognitive functioning at two years post diagnosis over SES and age at diagnosis. As reported in Table 14, percentile rankings of the ROCF at one year post diagnosis accounted for an additional 18% of the variance in adaptive functioning at two years post diagnosis when SES and age at diagnosis were taken into account (15% of the variance) and for an additional 13% of the variance in cognitive functioning at two years post diagnosis when SES and age at diagnosis were taken into account (32% of the variance). Both of the final equations were significant and accounted for 33% and 45% of the total variance respectively.

Percentile ranks and planning scores for the ROCF task were used in a prediction equation to determine how much of the variance in adaptive and cognitive functioning could be accounted for by these scores when combined in a single equation. Tables 15 and 16 outline the results of these regressions. SES and age at diagnosis accounted for 26% of the variance in adaptive functioning at one year post diagnosis. Percentile ranks and planning scores significantly accounted for 13% of additional variance over SES and age at diagnosis in adaptive functioning at the concurrent time point. The final equation was significant and accounted for 39% of the total variance. SES and age at diagnosis accounted for 15% of the variance in adaptive functioning at two years post diagnosis. Percentile ranks and planning scores accounted for 9% of additional variance at the concurrent time point and an additional 20% at the predictive time point (which was significant). SES and age at diagnosis accounted for 38% of the variance in cognitive functioning at one year post diagnosis. Percentile ranks and planning scores at one year post diagnosis significantly accounted for an additional 14% variance over SES and age at diagnosis in cognitive functioning at the concurrent time point. The final equation was significant and accounted for 52% of the total variance. SES and age at diagnosis accounted for 32% of the variance in cognitive functioning at two years post diagnosis. Percentile ranks and planning scores accounted for an additional 18% of the variance at the concurrent time point and the final equation was significant accounting for 51% of the total variance. Percentile ranks and planning scores accounted for an additional 17% of the variance at the predictive time points and the final equation was significant accounting for 50% of the total variance.

A three step regression model was analyzed to determine how much spatial skills (PA), percentile rankings, and spatial planning on the ROCF would account for variance in adaptive and cognitive functioning after SES and age at diagnosis was taken into account. Tables 17 and 18 outline these findings. PA scores and percentile rankings at one year post diagnosis significantly accounted for 12% of additional variance in adaptive functioning at the concurrent time point. When spatial planning was added to the equation, it contributed an addition 2% and the final equation with all three predictor variables was not significant. PA scores and percentile rankings at two years post diagnosis significantly accounted for 23% of additional variance in adaptive functioning at the concurrent time point. Again, spatial planning did not significantly contribute to the equation (an additional 2%) and the final equation was not significant. PA scores and percentile rankings at one year post diagnosis significantly accounted for an additional 19% of the variance in adaptive functioning at predictive time points. Spatial planning did not contribute significantly to the final equation.

PA scores and percentile rankings at one year post diagnosis significantly accounted for 33% of additional variance in cognitive functioning at the concurrent time point. Spatial planning did not significantly contribute to the final equation and the final equation with all three predictor variables was not significant. PA scores and percentile rankings at two years post diagnosis significantly accounted for 41% of additional variance in cognitive functioning at the concurrent time point. Again, spatial planning did not significantly contribute to the equation (an additional 3%) and the final equation was not significant. PA scores and percentile rankings at one year post diagnosis significantly accounted for an additional 23% of the variance in cognitive functioning at predictive time points. Spatial planning did not contribute significantly to the final equation.

Exploration of the subscales of the VABS revealed significant information regarding the Daily Living Skills (DLS) subscale. When it was used as an outcome measure instead of the Composite score the following information was obtained. As reported in Table 19, SES and age at diagnosis accounted for 5% of the variance in DLS at one year post diagnosis. Spatial skills (PA) and percentile rankings on the ROCF (1 year post) accounted for an additional 19% of the variance. The final equation was significant and accounted for 24% of the total variance in DLS at one year post diagnosis. At two years post diagnosis, SES and age at diagnosis accounted for 9% of the variance. Spatial skills (PA) and percentile rankings on the ROCF accounted for an additional 31% of the variance. The final equation was significant and accounted for 40% of the total variance in DLS at two years post diagnosis (Table 19). Spatial skills and percentile rankings at one year post diagnosis did not significantly predict DLS at two years post diagnosis (Table 19).

Exploration of the subscales of the SB:IV revealed significant information about the Verbal subscale. When used as an outcome measure instead of the Composite score the following information was obtained. SES and age at diagnosis accounted for 20% of the variance in verbal skills at one year post diagnosis. Spatial skills (PA) and percentile rankings at one year post diagnosis (additional 11%) and two years post diagnosis (an additional 24%) significantly accounted for additional variance in the Verbal subscale at concurrent time points after SES and age at diagnosis was taken into account (Table 20). Spatial skills (PA) and percentile rankings at one year post diagnosis accounted for an additional 8% of the variance at two years post diagnosis and the final equation was not significant (Table 20).

Table 3

Demographic and Medical Characteristics for Study Sample and Post Hoc Groups

	Study Sample (n=40)	Group 1 (n=19)	Group 2 (n=7)	Group 3 (N=7)	Group 4 (n=7)
Sex	41.9% Female	57.9% Female	42.9% Female	28.6% Female	28.6% Female
Race	27.9% Non-Caucasian	42.1% Non-Caucasian	14.3% Non-Caucasian	42.9% Non-Caucasian	0% Non-Caucasian
SES[a]	3.0 (SD = 1.18, Range 1.0-5.0)	3.0 (SD = 1.22, Range 1.0-5.0)	3.3 (SD = 1.38, Range 2.0-5.0)	3.1 (SD = 1.07, Range 2.0-5.0)	2.29 (SD = 1.38, Range 1.0-4.0)
Age at Diagnosis	8.6 (SD = 3.5)	5.84 (SD = .96)	11.57 (SD = 3.1)	10.86 (SD = 2.34)	10.43 (SD = 2.64)
Tumor Pathology					
Glioma/Astrocytoma	48.8%	52.6%	42.9%	42.9%	28.6%
PNET[b]	25.5%	26.3%	42.9%	14.3%	28.6%
Other	25.7%	21.1%	14.3%	42.9%	42.9%
Tumor Location	58.1% Non-Cortical Lesions	52.6% Non-Cortical Lesions	42.9% Non-Cortical Lesions	71.4% Non-Cortical Lesions	71.4% Non-Cortical Lesions

Note. [a] SES = Socioeconomic Status on a scale of 1 (high) to 5 (low) (Hollingshead, 1957)
[b] PNET = Primitive Neuroectodermal Tumor

Table 4

Adaptive (VABS) and Cognitive (Stanford Binet) Performance

	M	SD	Range
VABS – 1 year post-diagnosis			
Composite	92.38[a]	17.02	55-128
Communication	91.23[a]	14.68	54-118
Daily Living	96.55	15.66	61-134
Socialization	96.08	17.02	65-128
VABS – 2 years post-diagnosis			
Composite	90.35[a]	17.70	52-124
Communication	90.68[a]	17.82	52-123
Daily Living	91.38[a]	17.12	46-129
Socialization	93.85[b]	17.39	52-124
Stanford Binet – 1 year post-diagnosis			
Composite	96.85	16.74	68-125
Verbal	102.43	16.69	71-137
Visual	94.50	18.84	58-138
Quantitative	96.15	16.93	60-127
Short-Term Memory	96.58	16.02	57-121
Stanford Binet – 2 years post-diagnosis			
Composite	96.55	18.77	58-144
Verbal	100.49	17.02	59-135
Visual	95.78	19.22	60-133
Quantitative	96.23	18.89	58-130
Short-Term Memory	96.18	19.91	59-146

[a] Significantly different from normative sample (M=100) p<.01

[b] Significantly different from normative sample (M=100) p<.05

Table 5

Correlations among the outcome measures

	SES	Age at Dx	# of Treatments	Vineland Composite 1 year post	Stanford Binet Composite 1 year post	ROCF Planning 1 year post	Vineland Composite 2 years post	Stanford Binet Composite 2 years post	ROCF Planning 2 years post
SES	1	.03	.03	-.51**	-.55**	-.06	-.38*	-.47**	-.02
Age at Dx		1	.15	.04	.26	.77**	-.07	.31	.79**
# of Treatments			1	-.15	-.08	.09	-.15	.06	.02
Vineland Composite 1 year post				1	.73**	.28	.80**	.74**	.12
Stanford Binet Composite 1 year post					1	.47**	.64**	.88**	.35*
ROCF Planning 1 year post						1	.19	.51*	.75**
Vineland Composite 2 years post							1	.69**	-.20
Stanford Binet Composite 2 years post								1	.32*
ROCF Planning 2 years post									1

** Correlation is significant at the .01 level (2-tailed)
* Correlation is significant at the .05 level (2-tailed)

Table 6

Linear Regression of Spatial Planning on Adaptive (VABS) and Cognitive (SB:IV) Functioning at Concurrent Time Points

	VABS One year Post	VABS Two years Post	SB:IV One year Post	SB:IV Two years Post
SES				
β	-.49**	-.38*	-.52**	-.46**
sr^2	-.52	-.38	-.59	-.49
# of Treatments				
β	-.16	-.14	-.07	-.05
sr^2	-.20	-.15	-.15	-.06
Spatial Planning (ROCF)				
β	.27*	-.02	.45**	.31*
sr^2	.31	-.02	.53	.35
R^2	.35*	.17	.50**	.32*
Adjusted R^2	.29*	.10	.46**	.26*

*p<.057, **p<.01

Table 7

Linear Regression of Spatial Planning (one year post) on Adaptive (VABS) and Cognitive (SB:IV) Functioning at Predictive Time Points

	VABS Two years Post	SB:IV Two years Post
SES		
β	-.37*	-.44*
sr^2	-.38	-.51
# of Treatments		
β	-.16	-.09
sr^2	-.18	-.12
Spatial Planning (ROCF)		
β	.18	.49**
sr^2	.20	.56
R^2	.20	.47**
Adjusted R^2	.13	.42**

*p<.05, **p<.01

Table 8

Correlations among the subscales and potential predictor variables at one year post diagnosis

	%ile rank – one yr post	ROCF Planning 1 yr post	VABS Comm 2 yr post	VABS DLS 2 yr post	VABS Social 2 yr post	SB:IV Verbal 2 yr post	SB:IV Visual 2 yr post	SB:IV Quant 2 yr post	SB:IV STM 2 yr post
%ile rank - 1 yr post	1	.67**	.43**	.33*	.36*	.35*	.62**	.48**	.57**
ROCF Planning 1 yr post		1	.23	.14	.13	.35*	.58**	.36*	.48**

** Correlation is significant at the .01 level (2-tailed)
* Correlation is significant at the .05 level (2-tailed)

Table 9

Paired Sample Test of Stanford Binet – 4th Edition Subscales over time

	t	df	Sig.
Verbal	1.02	38	.31
Visual	-.66	39	.52
Quantitative	-.21	38	.83
Short Term Memory	.18	39	.86

Table 10

Correlation of Pattern Analysis with ROCF planning score and percentile rankings

	Pattern Analysis – 1 yr post	Pattern Analysis – 2 yrs post	ROCF Planning- 1 yr post	ROCF Planning- 2 yrs post	ROCF %ile – 1 yr post	ROCF %ile – 2 yrs post
Pattern Analysis – 1 yr post	1	.77**	.53**	.44**	.65**	.55**
Pattern Analysis – 2 yrs post		1	.61**	.49**	.62**	.66**
ROCF Planning – 1 yr post			1	.75**	.67**	.57**
ROCF Planning – 2 yrs post				1	.45**	.65**
ROCF %ile – 1 yr post					1	.65**
ROCF %ile – 2 yrs post						1

** Correlation is significant at the .01 level (2-tailed)

Table 11

Post Hoc Linear Regression of Spatial Ability (PA) on Adaptive (VABS) and Cognitive (SB:IV) Functioning at Concurrent Time Points

	VABS One year Post	VABS Two years Post	SB:IV One year Post	SB:IV Two years Post
SES				
β	-.34 *	-.13	-.23*	-.15
sr^2	-.35	-.14	-.35	-.25
# of Treatments				
β	-.04	-.28*	.08	.03
sr^2	.04	-.31	.14	.04
Spatial Planning (ROCF)				
β	.35*	.58**	.67**	.77**
sr^2	.34	.52	.73	.77
R^2	.35*	.38**	.71**	.72**
Adjusted R^2	.30*	.33**	.68**	.70**

*p<.056, **p<.01

Table 12

Post Hoc Linear Regression of Spatial Ability (one year post) on Adaptive (VABS) and Cognitive (SB:IV) Functioning at Predictive Time Points

	VABS Two years Post	SB:IV Two years Post
SES		
β	-.21	-.22
sr^2	-.21	-.27
Age at Diagnosis		
β	-.16	.16
sr^2	-.17	-.22
Spatial Skills (PA)		
β	.35*	.55**
sr^2	.31	.56
R^2	.23*	.54**
Adjusted R^2	.17*	.50**

*p<.055, **p<.01

Table 13

Post Hoc Linear Regression of Percentile Rankings of the ROCF on Adaptive (VABS) and Cognitive (SB:IV) Functioning at Concurrent Time Points

	VABS One year Post	VABS Two years Post	SB:IV One year Post	SB:IV Two years Post
SES				
β	-.40**	-.27	-.44**	-.46**
sr^2	-.42	-.27	-.49	-.49
# of Treatments				
β	-.11	-.27	.10	-.05
sr^2	-.12	-.24	.12	-.06
Spatial Planning (ROCF)				
β	.36*	.37	.37**	.31*
sr^2	.35	.30	.39	.35
R^2	.35*	.23	.47**	.32*
Adjusted R^2	.30*	.16	.43**	.26*

*p<.05, **p<.01

Table 14

Post Hoc Linear Regression of Percentile Rankings of the ROCF on Adaptive (VABS) and Cognitive (SB:IV) Functioning at Predictive Time Points

	VABS Two years Post	SB:IV Two years Post
SES	-.22	-.35*
β	-.24	-.40
sr^2		
Age at Diagnosis	-.30	.12
β	-.31	.14
sr^2		
Spatial Skills (PA)	.51**	.43**
β	.46	.43
sr^2	.33**	.45**
R^2	.27**	.40**
Adjusted R^2	-.22	-.35*

*p<.05, **p<.01

Table 15

Post Hoc Linear Regression of Percentile Rankings of the ROCF and Spatial Planning on Adaptive (VABS) and Cognitive (SB:IV) Functioning at Concurrent Time Points

	VABS One year Post	VABS Two years Post	SB:IV One year Post	SB:IV Two years Post
SES				
β	-.41**	-.26	-.46**	-.30*
sr^2	-.44	-.26	-.53	-.37
Age at Diagnosis				
β	-.33	-.18	-.15	.10
sr^2	-.25	-.13	-.13	.08
%ile Rankings (ROCF				
β	.21	.41*	.20	.60**
sr^2	.18	.31	.19	.51
Spatial Planning (ROCF)				
β	.37	-.14	.43	-.16
sr^2	.24	-.09	.31	-.12
R^2	.39*	.23	.52**	.51**
Adjusted R^2	.32*	.15	.47**	.45**

*p<.05, **p<.01

Table 16

Post Hoc Linear Regression of Percentile Rankings and Spatial Planning (one year post) on Adaptive (VABS) and Cognitive (SB:IV) Functioning at Predictive Time Points

	VABS Two years Post	SB:IV Two years Post
SES		
β	-.26	-.30*
sr^2	-.26	-.37
Age at Diagnosis		
β	-.18	.10
sr^2	-.13	.08
%ile Rankings (ROCF)		
β	.41*	.60**
sr^2	.31	.51
Spatial Planning (ROCF)		
β	-.14	-.16
sr^2	-.09	-.12
R^2	.23	.51**
Adjusted R^2	.15	.45**

*p<.059, **p<.01

Table 17

Post Hoc Linear Regression of Spatial Skill (PA) Percentile Rankings of the ROCF and Spatial Planning on Adaptive (VABS) and Cognitive (SB:IV) Functioning at Concurrent Time Points

	VABS One year Post	VABS Two years Post	SB:IV One year Post	SB:IV Two years Post
SES				
β	-.36*	-.10	-.25*	-.10
sr^2	-.22	-.11	-.36	-.18
Age at Diagnosis				
β	-.29	-.14	.01	.15
sr^2	-.22	-.11	.01	.18
Spatial Skill (PA)				
β	.16	.59**	.66**	.73**
sr^2	.13	.47	.63	.72**
%ile Rankings (ROCF				
β	.21	.13	-.03	.26
sr^2	.18	.11	-.04	.32
Spatial Planning (ROCF)				
β	.30	-.28	.12	-.32*
sr^2	.19	-.20	.11	-.34
R^2	.40*	.40*	.71**	.77*
Adjusted R^2	.31*	.32*	.67**	.73*

*p<.05, **p<.01

Table 18

Post Hoc Linear Regression of Spatial Skill (PA) Percentile Rankings and Spatial Planning (one year post) on Adaptive (VABS) and Cognitive (SB:IV) Functioning at Predictive Time Points

	VABS Two years Post	SB:IV Two years Post
SES		
β	-.21	-.23
sr^2	-.22	-.29
Age at Diagnosis		
β	-.43	-.03
sr^2	-.31	-.03
Spatial Skills (PA)		
β	.05	.40*
sr^2	.04	.38
%ile Rankings (ROCF		
β	.40	.12
sr^2	.31	.12
Spatial Planning (ROCF)		
β	.22	.23
sr^2	.13	.17
R^2	-.21	-.23
Adjusted R^2	-.22	-.29

*p<.05

Table 19

Post Hoc Linear Regression of Spatial Skill (PA) and Percentile Rankings of the ROCF on Vineland Daily Living Skills (VABS DLS)

	VABS DLS 1 yr post (concurrent)	VABS DLS 2 yrs post (concurrent)	VABS DLS 2 yrs post (predictive)
SES			
β	-.01	.05	-.10
sr^2	-.01	.06	-.10
Age at Diagnosis			
β	-.36	-.13	-.41
sr^2	-.24	-.10	-.28
Spatial Skills (PA)			
β	.46*	.70**	.19
sr^2	.33	.55	.15
%ile Rankings (ROCF)			
β	-.09	.17	.24
sr^2	-.07	.14	.18
Spatial Planning (ROCF)			
β	.28	-.41	.19
sr^2	.16	-.29	.11
R^2	.26*	.45*	.25**
Adjusted R^2	.15*	.37*	.14**

*p<.051, **p<.01

Table 20

Post Hoc Linear Regression of Spatial Skill (PA) and Percentile Rankings of the ROCF on Verbal Cognitive Ability (SB:IV Verbal Subscale)

	SB:IV Verbal – 1 yr post (concurrent)	SB:IV Verbal – 2 yrs post (concurrent)	SB:IV Verbal – 2 yrs post (predictive)
SES			
β	-.22	-.04	-.22
sr^2	-.22	-.05	-.21
Age at Diagnosis			
β	.03	.18	-.03
sr^2	.02	.15	-.02
Spatial Skills (PA)			
β	.30	.51**	.25
sr^2	.23	.43	.19
%ile Rankings (ROCF)			
β	.12	.35	-.01
sr^2	.09	.27	-.01
Spatial Planning (ROCF)			
β	.06	-.46	.23
sr^2	.04	-.33	.13
R^2	.31	.46*	.26
Adjusted R^2	.21	.38*	.14

*p<.056, **p<.01

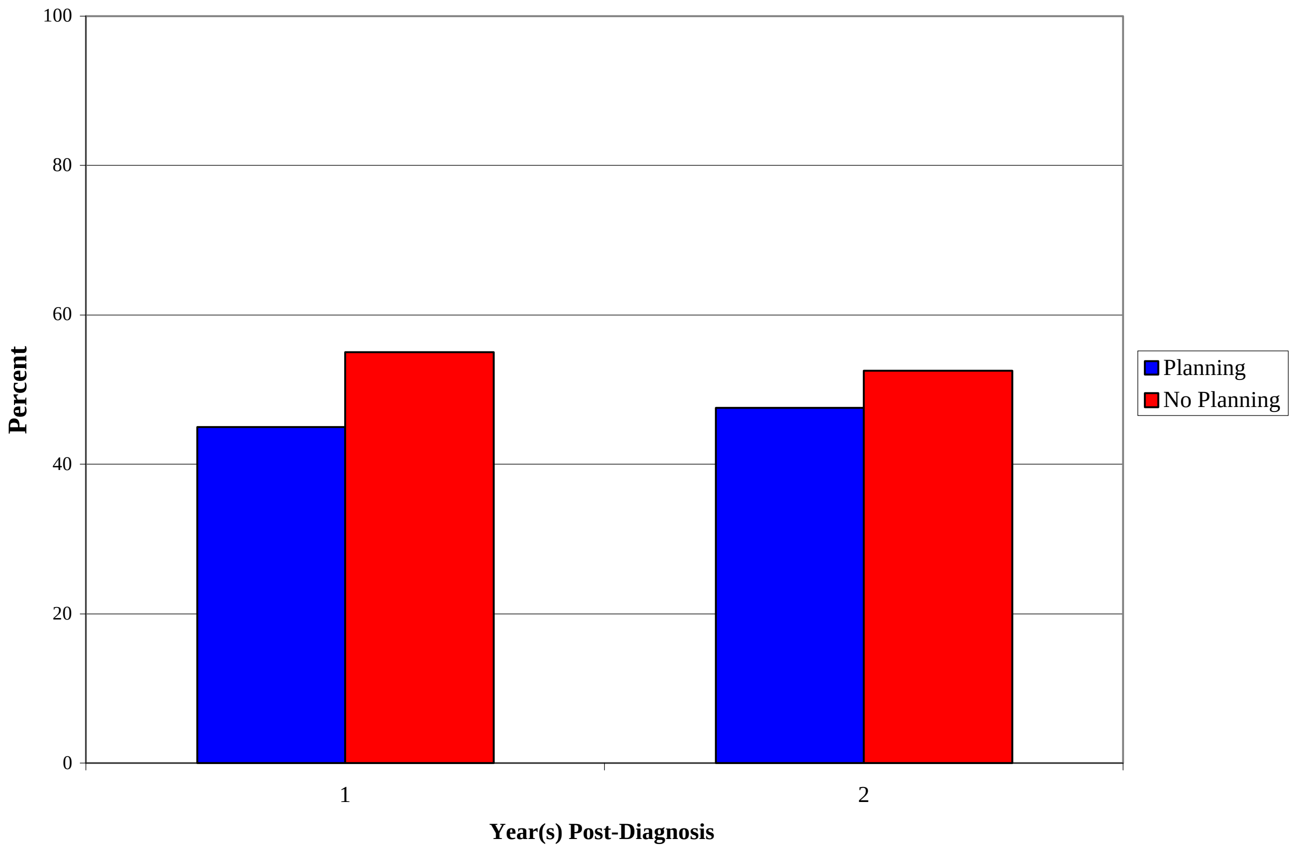

Figure 1. Percentage of participants who scored either one (Planning) or zero (No Planning) on the ROCF Spatial Planning Task

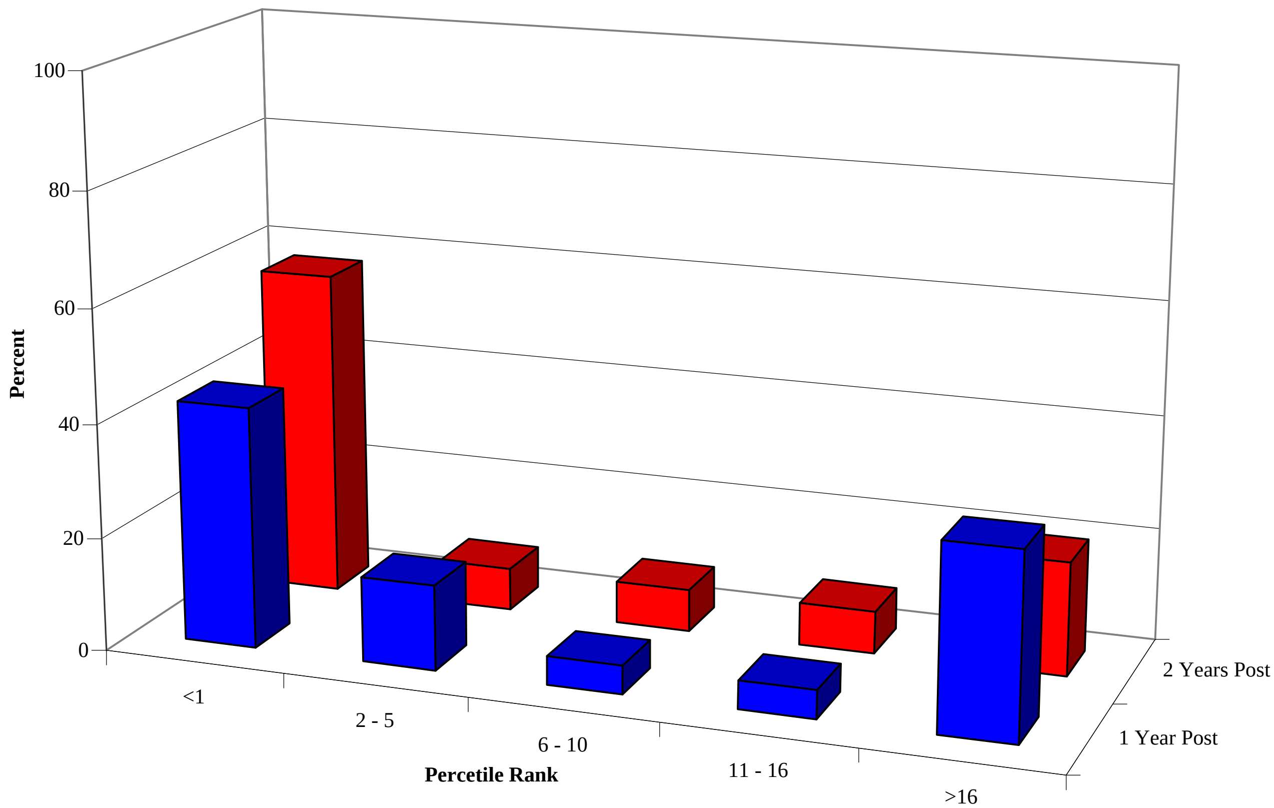

Figure 2. Percentage of participants at each age-adjusted percentile rank on the ROCF task at each time point

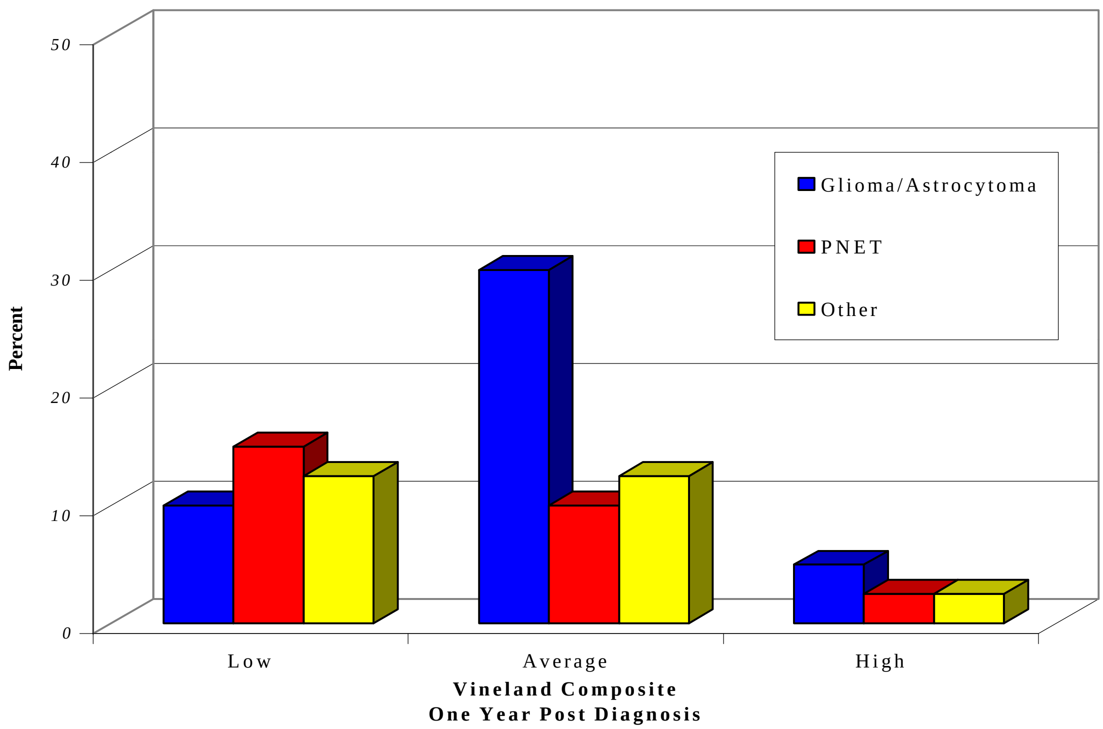

Figure 3. Tumor pathology frequency as a function of Vineland Composite scores at one year post diagnosis.

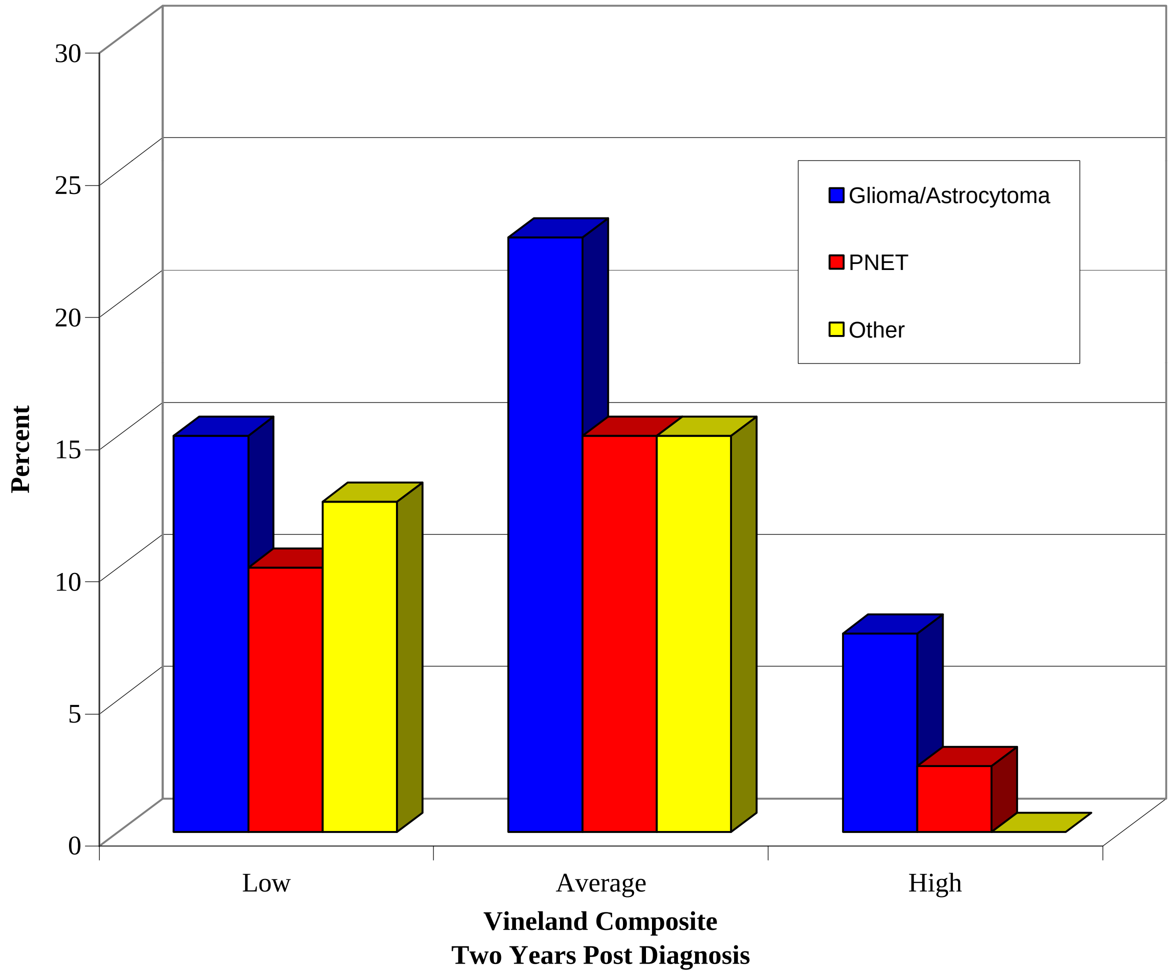

Figure 4. Tumor pathology frequency as a function of Vineland Composite scores at two years post diagnosis.

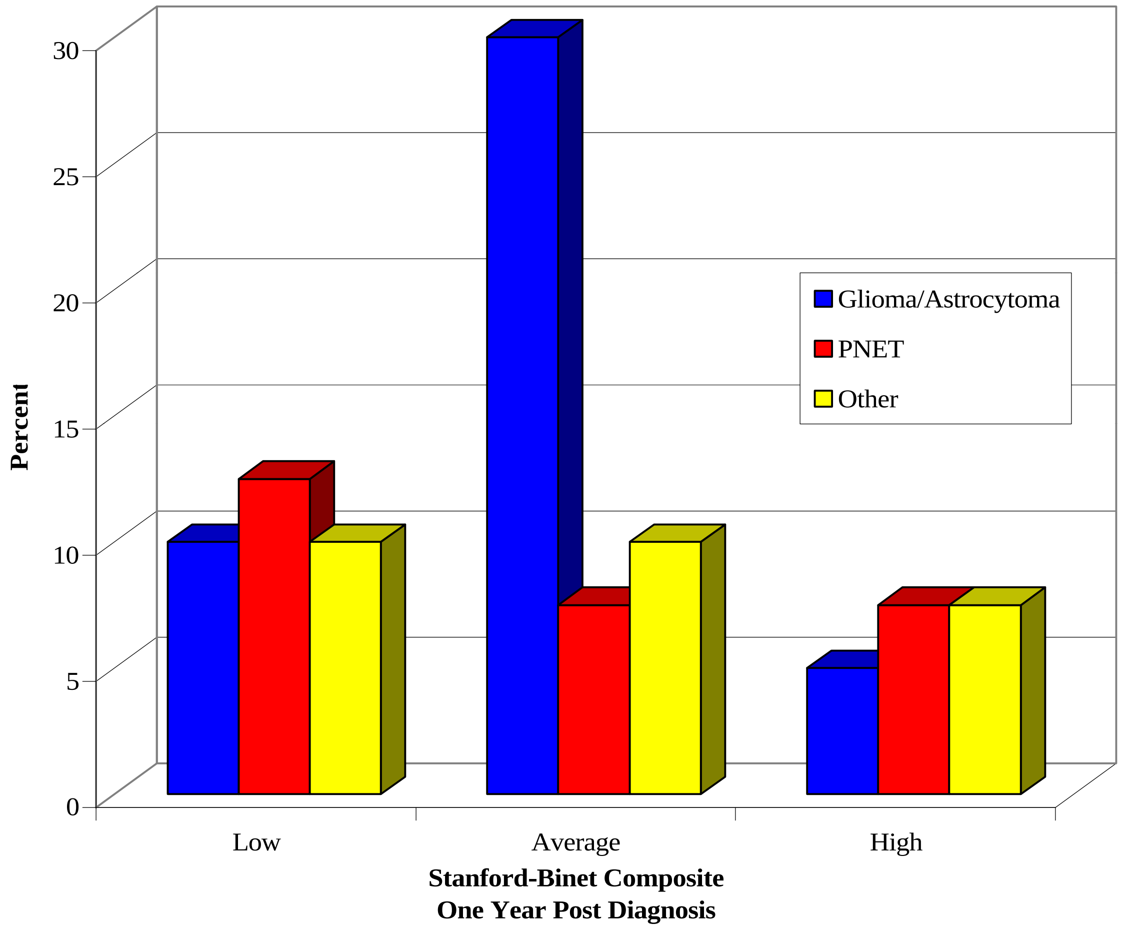

Figure 5. Tumor pathology frequency as a function of Stanford-Binet Composite scores at one years post diagnosis.

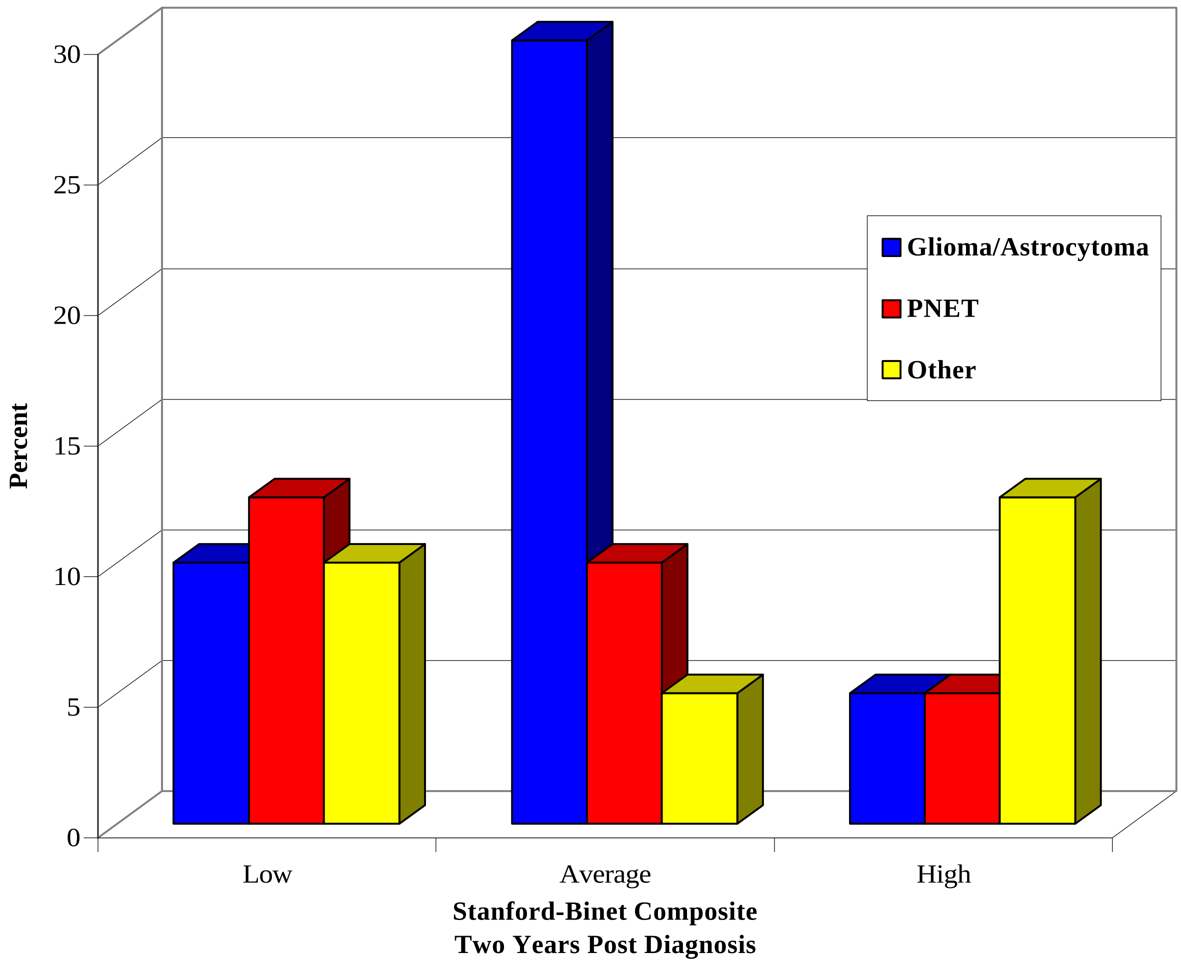

Figure 6. Tumor pathology frequency as a function of Stanford-Binet Composite scores at two years post diagnosis.

CHAPTER 5: DISCUSSION

The overall purpose of the current study was to investigate the relationship between executive functioning ability in children diagnosed with and treated for brain tumors, adaptive functioning, and cognitive functioning. More specifically, the intention of this study was to assess one aspect of executive functioning, spatial planning, and to examine its utility in predicting adaptive and cognitive functioning in children with brain tumors. Evidence suggests that impaired executive functioning in adults can impact severely their ability to function independently and successfully in life. This study sought to determine whether a similar relationship exists for developing children. It was hypothesized that spatial planning would be significantly associated with adaptive and cognitive functioning, and would enhance our understanding of specific functional impairments beyond that provided by other factors associated with the diagnosis and treatment of a brain tumor.

Jacobs and Anderson (2002) suggested that deficits in planning have significant functional impact on a child's quality of life, impeding academic progress, and limiting his or her capacity to maintain appropriate social relationships. Planning is said to have a broad impact on cognition and social development, leading to learning and adaptive function difficulties (Eslinger, Biddle, & Grattan, 1997; Marlowe, 1992). Previous research with adults suggests that an understanding of planning deficits in an adaptive context can contribute valuable information to the field. Several researchers (e.g., Boyd & Sautter, 1993; Eslinger, Grattan, & Geder, 1995) have demonstrated a significant relationship between planning and adaptive functioning in adults.

Lezak (1982), Luria (1973), and Yeates and Taylor (1998) developed theories linking executive functioning and real world functioning. They postulated that executive functions help a person to perform in a productive manner. However, when executive functions are impaired, there can be major ramifications for a person's adaptive functioning. These theorists suggest that those who have poor and impaired planning encounter significant difficulties in regulating their behavior and planning daily tasks in an adequate fashion.

Based on the previous research and these theories regarding the relationship between planning and adaptive functioning, this study anticipated finding significant relationships between them in this sample. This sample consisted of 40 children, ages 6 to 16, diagnosed and treated for brain tumors. The participants were evaluated with the ROCF, SB:IV, and the VABS at an average of one year post-diagnosis and again at an average of two years post-diagnosis. The sample was similar to other samples of children with brain tumors that have been studied in the research literature. They were similar to the previous samples on both medical and demographic variables.

With regard to predictor and outcome variables, the participants scored lower than normative samples of children on spatial planning ability and adaptive functioning. Akshoomoff and Stiles (1995) found that over 60% of typical children will obtain a planning score of 3 with the BQSS Planning score criteria indicating some planning ability with moderate planning deficits. Over 50% of the current sample obtained BQSS Planning scores of zero at both one year and two years post diagnosis, indicating that the participants demonstrated little or no planning strategy on the ROCF task at those time points. The current sample demonstrated average adaptive functioning as measured by the VABS; however, the Composite and Communication subscale scores were significantly below the normative sample at one year post diagnosis. Additionally, the Composite and Communication, Daily Living, and Socialization subscale scores were significantly below the normative sample at two years post diagnosis. These participants scored in the average range on cognitive functioning as measured by the SB:IV and their scores were not significantly different from the normative sample at either time point.

The results of this investigation did not provide support for the use of spatial planning skills as a unique predictor of adaptive functioning at one year or two years post diagnosis. With regard to cognitive functioning, spatial planning skill was an important predictor, accounting for a significant amount of variance at both one year and two years post diagnosis. The second hypothesis predicted that spatial planning ability at one-year post diagnosis would predict functional ability at two years post diagnosis better than SES and number of treatments. The hypothesis was not supported with regard to adaptive functioning; however, spatial planning ability at one-year post diagnosis did significantly predict cognitive outcomes.

A potential reason for these findings may be related to skill stability over time. Since the study spans two years post diagnosis of a brain tumor, and changes in variance were implicit in the initial hypotheses, it is important to consider the role of skill stability in these results. Cognitive functioning was stable over the two time points; there was no significant difference between participants' scores at one-year post diagnosis and scores at two years post diagnosis. Adaptive functioning was stable over all; however, Daily Living Skill scores declined from one year post diagnosis to two years post diagnosis. The planning score and percentile rankings of the ROCF also were stable over the two time points.

This stability of functioning over time is not consistent with the previous literature. Eslinger et al. (1997) reviewed cases of childhood brain tumors and found significant alterations in adaptive functioning in spite of generally persevered intellect, language, perception, and memory. Eslinger and colleagues (1995) suggested that there may be delayed effects with respect to changes in cognitive processes, particularly executive functions, and for social cognition and related behaviors. Eslinger and colleagues (1997) stated that executive skills may appear to worsen with time as a result of a widening discrepancy between expected and actual development of functioning. More importantly, these deficits may adversely affect an individual's adaptation throughout the lifespan, more so than intellectual and sensorimotor deficits.

Similar findings of change over time were expected in this study; however, the overwhelming stability of adaptive functioning and spatial planning skills over the time period studied may have contributed to the lack of findings in this area, due to the lack of variability in results. If the expectation was to predict outcomes from an earlier time point, variability in adaptive functioning and spatial planning skills over time is necessary to see such a relationship. Additionally, the time period from one year post diagnosis to two years post diagnosis may not have been a long enough period of time since diagnosis to see the effect Eslinger had postulated.

A significant correlation was found between spatial skills as measured by the Pattern Analysis subtests of the SB:IV and spatial planning ability and spatial skills also were stable over time. Spatial skill was used to determine if it significantly predicts adaptive and cognitive functioning. Spatial skills accounted for a significant amount of variance in both adaptive and cognitive skills. These results suggest that it is spatial skill and not spatial planning that predicts adaptive functioning.

Another reason for the lack of the hypothesized findings was because the BQSS Planning score may not be a sensitive enough measure to differentiate the range of spatial planning abilities in children diagnosed with and treated for brain tumors. The BQSS Planning measure has specific scoring criteria (see Stern et al., 1994), but a limited quantitative range of results. The scores are 4 (no planning deficits), 3 (mild planning deficits), 2 (moderate planning deficits), 1 (significant planning deficits), and zero (extreme planning deficits or no evidence of a planning strategy). Scores 1 through 4 indicate that the participant demonstrates some evidence of a planning strategy. Over half of the participants in this study scored a zero (no evidence of planning strategy) at both time points. The other 45-47% scored between 1 and 4. The sample size of these latter groups was very small and there was no indication that they were significantly different from one another on related measures. Therefore they were combined to make one group of children who had at least some planning ability and were compared to those rated as having no planning ability. This scaling or combination of scores may have been problematic because children at the lower end of the scored spectrum were not differentiated. Akshoomoff and Stiles (1995) attempted to address this issue by describing starting and progression strategies in order to get a better qualitative view of children's spatial planning skills taking development into account. However, by age 9, typical children should be able to plan and copy the figure in an adult-like manner and children as young as 6 will use some planning strategy to copy the figure. The significant deficits seen in this sample resulted in a scoring floor effect which also restricted the predictive variance in our models.

Other Medical Factors

In addition to the variables discussed above, medical factors have been studied in relation to the impact of a lesion on the brain. Past research has also suggested that the timing of a lesion has more of an impact on brain development than the nature of the lesion itself (Capone, 1996). A younger age at diagnosis consistently has been associated with increased neuropsychological impairment (Chapman et al., 1995; Kun et al., 1983; Mulhern et al., 1992; Spunberg et al., 1981). The results of the current study are consistent with this line of research. Significant relationships were found between age at diagnosis and performance on the ROCF task.

Although Kennard (1940, 1942) initially posited that early brain damage has fewer harmful outcomes than that occurring later in life, he later found this type plasticity does not apply to lesions of the prefrontal and other cortical areas. Later studies found an interaction between age of lesion onset and pattern of behavioral impairment, with results ranging from immediate to delayed expression of behavioral problems to complete or partial recovery (Aram & Ekelman, 1986; Dennis & Barnes, 1993).

In addition to injury timing, injury location was examined in the current study. The results were not as expected and therefore post hoc analyses were performed in order to better understand the data and results. A closer examination of medical and background factors offered more information about effects of tumor location in this sample. Although history of a brain tumor significantly impacted adaptive behavior scores, tumor location did not significantly effect those scores. The same is true of ROCF scores; there was no significant relationship between tumor location and spatial planning. Tumor pathology also was not significantly associated with a change in adaptive, cognitive, or planning scores.

Although the majority of the current sample did not sustain direct insult to the prefrontal area, the structural and functional integrity of the neurological systems contributing vital inputs to the prefrontal area may have been compromised. Eslinger et al. (1997) have posited that cerebral damage impacts normal development of the injured areas as well as normal maturation of other areas to which it is functionally connected. Executive functioning is a complex function which is dependent upon interconnections among several areas of the brain (Capone, 1996), consistent with Luria's (1973) theory of the tertiary zone of cortical functioning. This zone is associative, involving intercommunication between several areas of the brain and integrating information from all sensory modalities to perform higher-order cognitive functions. The development of tertiary zones is not complete until early adulthood (Mrzljak et al., 1990). This theory is consistent with biological evidence suggesting that prefrontal functions are less dependent on synaptic density and more dependent on the utilization and arrangement of synaptical connections (Changeux et al., 1984) and neuronal maturation in prefrontal regions is believed to occur into puberty (Mrzljak et al., 1990).

Nonfrontal areas of the brain in which the occurrence of lesions may impact prefrontal functions include subcortical areas such as the caudate nucleus of the basal ganglia (Brouwers et al., 1985), thalamus (Herron et al., in press), and subcortical white matter (Rourke, 1989), the temporal lobe (Nestor et al., 1993), and the posterior fossa (LeBaron et al., 1988; Mostofsky et al., 1998). This line of thinking is consistent with this study’s finding that although there was a high incidence of moderate to severe executive functioning (spatial planning) impairment, most (57.5%) of tumors were located sub-cortically and only 7 children (17.5%) had a tumor in the frontal lobe.

The current study’s results are not consistent with what has traditionally been referred to as the Kennard principle of brain plasticity and, instead, are consistent with his later findings regarding the exception of higher-level areas. The findings are somewhat inconsistent with the vulnerability hypothesis, also known as the Dobbing hypothesis, which asserts that cerebral damage during development has its greatest impact on those areas experiencing the greatest rate of growth and/or organization at that time (Aylward, 1997). In the current sample, it appears that adverse late effects occurred for executive functioning, particularly for children diagnosed at an early age, even though these abilities are not fully developed until early adulthood. It appears that these functions have an extended period of vulnerability.

Limitations of the Study

Some caution should be noted in the interpretation and generalization of the findings of this research study because of important limitations. Generalization is compromised because the children in this study, while representative of children diagnosed and treated with brain tumors in a large southern state, may be different in important ways from other populations of children diagnosed and treated for brain tumors in other locations. For example, hospital systems and treatment procedures from this area may be substantially different from those in other areas, or the common types of injuries may differ in various geographic locations. Participation in this investigative study was contingent upon having completed two separate psychological evaluations that each included a SB:IV, VABS, and the ROCF task. This excluded a number of children and significantly reduced the sample size. Finally, in many cases, some of the treatments children received at the time of this study differ from those that are currently available, limiting generalization somewhat to current and future populations of children diagnosed and treated for brain tumors.

Some statistical limitations also exist in this present investigative study. The small sample size prevented numerous comparisons that would have been desired. Because of the small sample size, a limited number of predictor variables were utilized. However, even with the small sample size, power was sufficient to detect differences. Post hoc power (based on the observed effect sizes) ranged from .51 to .98 in this study. Although the situations in which power was low (e.g., .51) indicated that a large sample size would have been better for the analysis, most analyses involved higher power. In addition to power limitations based on the small sample size of the investigation, dichotomous coding of several of the variables may also have resulted in the loss of information as pertained to the variability in the data, which also serves to reduce power.

Participant attrition is a factor inherent to longitudinal studies that must be considered. Attrition due to geographic relocation or lack of motivation to continue in the project may not be as concerning as attrition due to morbidity. This is because children lost to this study on the basis of morbidity may likely represent a severity of illness and treatment factors that was not accounted for in this study.

Additionally, selection of executive functioning measures was limited by those measures already incorporated into the study protocol for the longitudinal study. This study explored executive functioning in a limited manner (Spatial Planning with the ROCF). It would have been desirable to have an additional planning task without the constraints of motor performance for success. It would also have been desirable to delve more into the important relationship of the role of spatial abilities with motor abilities. This role simply cannot be overestimated.

Implications of the Study

From a theoretical perspective, the results of this study suggest that the use of executive tasks may offer some utility in the understanding of cognitive ability in children diagnosed with and treated for brain tumors. This study suggests that aspects of the child's executive functioning are important in the cognitive outcomes in this population. However, with a large portion of the variance unaccounted for in adaptive functioning, and an inability to predict global day-to-day functioning, exploration of other factors is warranted.

Demonstration of a relationship between executive deficits and everyday functioning would help substantiate the impact of neuropsychological impairment on an individual's everyday life, thus supporting the ecological validity of neuropsychological assessment (Tupper and Cicerone, 1990). The results of this study have practical implications for the screening of children with brain tumors. The data support the ecological validity of the use of spatial skills for predicting functional ability in children diagnosed and treated for brain tumors. The ROCF task is relatively quick and easy to administer and can provide very useful information regarding potential problems in functional ability. This information can be critical in the development of appropriate remediation strategies to assist a child with a brain tumor in acquiring the necessary adaptive and cognitive skills for daily functioning.

Despite this study's demonstration of adaptive behavior deficits and average cognitive functioning in children diagnosed and treated for brain tumors, group means obscure the exceptional outcome of some children. There are individual differences in the way tumors impact the brain, complications accompanying diagnosis and treatment, and in the way each brain responds to a particular neurological insult. Eslinger et al. (1997) have addressed this issue in their hypothesis that the course of altered development following childhood cerebral injury is neither simple nor linear.

Conclusion

Future research should continue to ask questions that will impact how we understand executive, adaptive, and cognitive functioning outcomes in those children who have been diagnosed and treated for brain tumors. Timely interventions commenced as soon as possible following the injury are important because these deficits may adversely affect an individual's adaptation throughout the lifespan, more so than cognitive and intellectual deficits. Ongoing research evaluating functional ability and executive functioning in children with brain tumors is needed in order to assess the outcomes of the cognitive rehabilitative interventions currently in use. Additional variables already used with this population which may be the focus of future research include the use of medications to improve attention and impulse control, use of tools such as calendars and daytimers to improve planning and organization skills, and interventions such as problem solving groups, behavior management programs, individual and group counseling, and one-on-one mentoring.

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