EXECUTIVE FUNCTIONING IN CHILD SURVIVORS OF

PEDIATRIC CEREBELLAR ASTROCYTOMAS

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DEDICATION

I dedicate this dissertation to my wife, Deirdre, and to my family.

I am not afraid of the obstacles that I may face, for I do not stand alone.

EXECUTIVE FUNCTIONING IN CHILD SURVIVORS OF

PEDIATRIC CEREBELLAR ASTROCYTOMAS

by

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DISSERTATION

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Children treated for cerebellar pilocytic astrocytomas (CPA) were once thought to have minimal cognitive impairment given the cerebellar location of the tumor and its typical treatment consisting of surgical resection with no radiation or chemotherapy. However, research has recently shown that these children display a variety of cognitive problems. Despite the increased focus on cognitive functioning in this population, executive functions (EF) have not been well studied. The current study examined EF in pediatric CPA survivors through the use of clinical assessment and behavioral rating scales. Emotional and behavioral functioning were examined through rating scales as an additional objective.

Twenty children who underwent surgery for CPA and were between the ages of eight and 16 years participated in the study. Each child was administered a multidimensional neuropsychological battery of EF, which consisted of the Delis-Kaplan Executive Function System, Wisconsin Card Sorting Test, and the subtests comprising the Working Memory Index from the Wechsler Intelligence Scale for Children - Fourth Edition. Parents and teachers completed the Behavior Rating Inventory of Executive Function (BRIEF) and the Behavior Assessment System for Children - Second Edition (BASC-2).

No significant differences were found between the CPA group's performance on the clinical measures and the normative test means. Teacher ratings on the BRIEF showed that the CPA group exhibited significantly more difficulties with working memory, whereas parent ratings showed significantly more difficulties with inhibition, mental flexibility, emotional control, initiation of activities, working memory, planning/organization, and monitoring behavior. In terms of emotional and behavioral functioning on the BASC-2, parents rated the CPA group as exhibiting significantly more difficulties with depression, withdrawal, and overall behavioral problems. Parent ratings on the BASC-2 also showed significantly more problems in several areas of adaptive functioning. This study did not replicate the findings of previous studies on EF in pediatric CPA samples. Although EF impairments were not evident, the CPA sample exhibited subtle and mild EF and behavioral/emotional difficulties.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF APPENDICES

CHAPTER ONE
Introduction

The high incidence of childhood brain tumors and the significant improvement in the rate of cancer survivorship has led to an increased focus on the impact of cancer treatment on cognitive and behavioral functioning. According to the American Cancer Society (2006), there will be an estimated 9,500 new pediatric cases of cancer in the United States in 2006, approximately 22% of which will be tumors located in the brain and nervous system. Treatment regimens for these young patients include combinations of surgery, radiation, and chemotherapy. Due to advances in medicine, the five-year survival rate for children with brain and nervous system tumors is 73% (American Cancer Society).

The deleterious effects of the medical treatments on the developing brains of these children often result in a variety of short- and long-term cognitive deficits. Intelligence, memory, language, visual-spatial, executive function, and motor impairments have been found in children after treatment consisting of cranial irradiation and some chemotherapeutic agents (George et al., 2003; Konczak, Schoch, Dimitrova, Gizewski, & Timmann, 2005; Maddrey et al., 2005). As a result of their cognitive deficits, children experience difficulties in academics and frequently require special services in school. These children also experience behavioral, emotional, and social difficulties following their treatment (Upton & Eiser, 2006).

Research on brain tumors and lesions has increased our understanding of the functions of different areas of the brain and has led to revised conceptualizations of the functional role of certain brain structures. For example, recent research has shown that the cerebellum plays a role in a variety of functions that were previously not attributed to this structure (Aarsen, Van Dongen, Paquier, Van Mourik, & Cateman-Berrevoets, 2004; Ater et al., 1996; Exner, Weniger, & Irle, 2004; Gottwald, Wilde, Mihajlovic, & Mehdorn, 2004; Hokkanen, Kauranen, Roine, Salonen, & Kotila, 2006; Kalashnikova, Zueva, Pugacheva, & Korsakova, 2005; Levisohn, Cronin-Golomb, & Schmahmann, 2000; Karatekin, Lazareff, & Asarnow, 2000; Malm et al., 1998; Molinari, Petrosini, Misciagna, & Leggio, 2004; Neau, Arroyo-Anllo, Bonnaud, Ingrand, & Gil, 2000; Riva & Giorgi, 2000; Steinlin et al., 2003). Interestingly, children treated for cerebellar tumors have demonstrated high rates of cognitive impairments, despite the fact that the role of the cerebellum has typically been thought to largely be confined to coordination of movement, balance, and posture. Although some of these deficits can be attributed to negative treatment effects, such as those from radiation, other children treated for cerebellar tumors with only surgery still exhibit cognitive impairments (Aarsen, Van Dongen, Paquier, Van Mourik, & Catsman-Berrevoets, 2004; Beebe et al., 2005; Karatekin, Lazareff, & Asarnow, 2000; Steinlin et al., 2003). Further supporting the cerebellum's role in cognitive functions, studies on patients with cerebellar lesions have commonly found memory, working memory, attention, and visual spatial impairments (Gottwald, Wilde, Mihajlovic, & Mehdorn, 2004; Exner, Weniger, & Irle, 2004; Kalashnikova, Zueva, Pugacheva, & Korsakova, 2005; Malm et al., 1998). Recent studies have also shown lateralization of cognitive function in the cerebellum. For instance, research on cerebellar tumors has found that right cerebellar tumors can result in verbal deficits, while left cerebellar tumors can result in visual-spatial deficits, and tumors in the vermis can lead to behavioral and emotional disturbances (Riva & Giorgi, 2000).

Although children treated for cerebellar pilocytic astrocytomas (herein referred to as CPA) were thought to have better prognosis and minimal cognitive impairment due to their treatment, which typically consists of surgery with no radiation or chemotherapy, various studies have shown that these children tend to display a variety of cognitive deficits. However, the presence of executive function problems in child survivors of CPA has not been well studied. Executive functions are higher-level cognitive functions that are involved in planning, problem solving, allocating attention, working memory, and regulating impulses (Zillmer & Spiers, 2001). Executive functions play a large role in people's ability to function adequately in work or school, as well as controlling their emotions and behaviors.

Few studies have focused on executive functioning in children treated for CPA. The studies that exist have small sample sizes or limited assessment of executive functions (Aarsen, Van Dongen, Paquier, Van Mourik, & Catsman-Berrevoets, 2004; Karatekin, Lazareff, & Asarnow, 2000). Given the ramifications of cognitive impairments, particularly executive function deficits, on a child's academic, psychological, and social functioning, more information is needed in order to better assess deficits and develop interventions that can reduce the severity of problems or provide support.

The purpose of the current study was to further investigate executive functioning in a pediatric population treated for CPAs. The evaluation was multidimensional and included a range of tasks to test executive functioning. Moreover, the study explored patients' executive functioning behaviors in the home and school environments and examined whether observable differences existed. A comprehensive assessment of executive functions was meant to provide greater detail regarding the level of impairment in this population.

The following is a review of relevant literature pertaining to executive functioning in childhood survivors of cerebellar astrocytomas. The review will begin with a discussion of the cerebellum, normal cerebellar function, and its circuitry. Executive functions will then be reviewed, followed by a discussion of the development and neuroanatomical circuitry of executive functions. Cerebellar pathology will also be discussed, followed by a review of cognitive deficits in patients with posterior fossa tumors. The review will conclude with an examination on the current state of the literature on executive function deficits in children treated for CPA.

CHAPTER TWO
Review of the Literature

THE CEREBELLUM

Normal Cerebellar Function

The cerebellum plays a fundamental role in the control of movement and posture. It is involved in various voluntary motor functions, such as coordinating the timing of muscles, as well as learning and modifying motor skills (Bastian & Thach, 2002; Massaquoi & Tolpka, 2002). In terms of posture, the cerebellum assists in orienting the body in space, helping the muscles maintain the body's posture, and controlling muscle tone during voluntary movement (Zillmer & Spiers, 2001).

The cerebellum is located below the posterior portion of the cerebral hemispheres, just above the pons and medulla. It consists of two cerebellar hemispheres and a medial region termed the vermis. The cerebellum attaches to the brain stem via the cerebellar peduncles (Zillmer & Spiers, 2001). It is divided into the anterior, middle, and flocculonodular lobes (Kandel, Schwartz, & Jessel, 2000). The cerebellum contains four pairs of deep nuclei which aid in its functioning: these are the dentate, fastigius, globose, and emboliform nuclei (Brodal, 1981; Brodal, 1992; Kandel et al., 2000). The cellular structure of the cerebellum is comprised of neurons organized in repeating patterns. These include Purkinje and granule cells (Colin, Ris, & Godaux, 2002). Approximately seven-eighths of all neurons in the brain are located in the cerebellum, thus it contains more neurons and synapses than the rest of the brain (Colin et al., 2002; Williams & Herrup, 1988). Also, studies have shown that the cerebellum receives input from nearly all levels of the central nervous system (Salman, 2002). This is interesting given that, historically, the cerebellum's role was considered to be solely of motor.

Recent findings have led to increased understanding of the cerebellum's role in non-motor functions. The cerebellum has been implicated in attention, fluency and prosody of language, and visual-spatial abilities, such as spatial memory and visual-spatial organization. Of interest to the proposed project, the cerebellum is also involved in different components of executive functions; these include planning, abstract reasoning, and working memory (Akshoomoff & Courchesne, 1992; Allen, Buxton, Wong, & Courchesne, 1997; Courchesne et al., 1994; Desmond, Gabrieli, Wagner, Ginier, & Glover, 1997; Garavan, Ross, Li, & Stein, 2000; Kim, Ugurbil, & Strick, 1994; Salman, 2002; Townsend et al., 1999). Executive functions, visual-spatial abilities, language, and memory appear to involve the cerebellar hemispheres and dentate nucleus (Aarsen, Van Dongen, Paquier, Van Mourik, & Cateman-Berrevoets, 2004; Ater et al., 1996; Exner, Weniger, & Irle, 2004; Gottwald, Wilde, Mihajlovic, & Mehdorn, 2004; Kalashnikova, Zueva, Pugacheva, & Korsakova, 2005; Levisohn, Cronin-Golomb, & Schmahmann, 2000; Karatekin, Lazareff, & Asarnow, 2000; Malm et al., 1998; Riva & Giorgi, 2000; Steinlin et al., 2003). Specifically, cognitive functions have been shown to be mediated by the lateral, posterior, and inferior regions of the cerebellar cortex, as well as in the lateral inferior region of the dentate nucleus (Bastian & Thach, 2002; Riva & Giorgi, 2000; Schmahmann & Sherman, 1998).

Cerebellar Circuitry

Functional Organization

The cerebellum can be divided into three functionally distinct lobes: the vestibulocerebellum, spinocerebellum, and cerebrocerebellum. These regions are also termed the archicerebellum, paleocerebellum, and neocerebellum, respectively. Each lobe is defined by its connections to other brain structures. The vestibulocerebellum, located in the flocculonodular lobe, receives input from the vestibular nerve and vestibular nuclei and controls equilibrium, posture, and eye movements. The spinocerebellum receives somatosensory input from the spinal cord and limbs and is involved in posture and voluntary movements. It consists of the anterior lobe and the medial portion of the posterior lobe, which include the vermis and paravermis. The cerebrocerebellum, which receives input from the cerebral cortex, has been shown to be involved in planning, mental rehearsal, and execution of complex motor actions. It consists of the majority of the posterior lobe (Brodal, 1981; Brodal, 1992; Kandel, Schwartz, & Jessel, 2000; O'Hearn & Molliver, 2001; Schmahmann, 1991).

The functions of the specific nuclei in the cerebellum have also been described. The fastigius is involved in control of eye movements, equilibrium, upright stance, and gait. The fastigius serves as the output for the vestibulocerebellum. The interposed nucleus, which consists of the globose and emboliform nuclei, plays a role in modulation of stretch, contact, placing and other reflexes. The interposed nuclei receive input from the spinocerebellum. The dentate is involved in voluntary movement of the limbs and has also been shown to be involved in aspects of cognitive functioning. The dentate nuclei serve as the output for the cerebrocerebellum (Asanuma, Thach, & Jones, 1983; Bastian & Thach, 2002; Dum & Strick, 2003; Hendleman, 2000; Middleton & Strick, 1994).

The cerebellum has also been organized into topographical regions pertaining to cognitive, emotional, and sensorimotor functions. The term "limbic cerebellum" has been used to describe regions in the cerebellum that are thought to be involved in emotion, affect, and fight or flight defense mechanisms, such as the floccunodular lobe, vermis, and fastigius and globose nuclei (Schmahmann, 1991). Support for the limbic cerebellum is derived from studies that have shown connections between the cerebellum and specific areas in the limbic system (Heath, Dempsey, Fontana, & Myers, 1978; Peters & Monjan, 1971; Sacchetti, Scelfo, Tempia, & Strata, 2004; Snider & Maiti, 1976). Lesions to areas in the human cerebellum have also been shown to result in behavioral and emotional disturbance (Levisohn, Cronin-Golomb, & Schmahmann, 2000; Riva & Giorgi, 2000; Schmahmann & Sherman, 1998; Steinlin et al., 2003). The sensorimotor region of the cerebellum consists of the anterior lobe and the medial aspect of the posterior lobe (Brodal & Bjaalie, 1997; Dum & Strick, 2003). A functionally separate region of the cerebellum involved in cognitive function includes the lateral cerebellar hemispheres of the posterior lobe and the dentate and emboliform nuclei. These areas have been implicated in aspects of memory, learning, executive function, and language (Exner, Weniger, & Irle, 2004; Kalashnikova, Zueva, Pugacheva, & Korsakova, 2005; Schmahmann, 1998).

Recent research has also suggested that cerebellar hemispheres process cognitive functions that are associated with the contralateral cerebral hemisphere (Gottwald, Wilde, Mihajlovic, & Mehdorn, 2004; Hokkanen, Kauranen, Roine, Salonen, & Kotila, 2006; Kalashnikova, Zueva, Pugacheva, & Korsakova, 2005; Levisohn, Cronin-Golomb, & Schmahmann, 2000; Molinari, Petrosini, Misciagna, & Leggio, 2004; Riva & Giorgi, 2000; Steinlin et al., 2003); however, several studies have not found these results (Aarsen, Van Dongen, Paquier, Van Mourik, & Berrevoets-Berrevoets, 2004; Beebe, Ris, Armstrong, Fontanesi, Mulhern, Holmes, & Wisoff, 2005; Neau, Arroyo-Anllo, Bonnaud, Ingrand, & Gil, 2000). It is hypothesized that verbal skills are processed in the right cerebellar hemispheres and nonverbal, visual-spatial skills are processed in the left cerebellar hemispheres (Gottwald, Wilde, Mihajlovic, & Mehdorn, 2004; Hokkanen, Kauranen, Roine, Salonen, & Kotila, 2006; Kalashnikova, Zueva, Pugacheva, & Korsakova, 2005; Levisohn, Cronin-Golomb, & Schmahmann, 2000; Molinari, Petrosini, Misciagna, & Leggio, 2004; Riva & Giorgi, 2000; Steinlin et al., 2003). The vermis is thought to mediate behavioral and emotional function since lesions to the vermis have been shown to result in affective and behavioral disturbance (Levisohn, Cronin-Golomb, & Schmahmann, 2000; Riva & Giorgi, 2000; Salman, 2002; Schmahmann & Sherman, 1998; Steinlin et al., 2003). As discussed above, the cerebellum receives information from several regions throughout the central nervous system, including the spinal cord and cerebral cortex. However, only the frontal cortex connections with the cerebellum will be discussed below, as these are most relevant to the proposed project.

Connections from the Frontal Lobes

Afferent fibers deliver information from the central nervous system to the cerebellum. Research conducted on these anatomic substrates has shown that the cerebral cortex sends information to the cerebellum through the corticopontocerebellar, cerebro-olivocerebellar, and cerebroreticulocerebellar pathways (Schmahmann, 1991; Snell, 1997, Voogd, 2003). Information from the cerebral cortex is conveyed to the cerebellum predominantly through the corticopontocerebellar pathway, which has been implicated in cognitive function (Brodal & Bjaalie, 1997; Schmahmann, 1991; Schmahmann & Pandya, 1995, 1997; Snell, 1997, Voogd, 2003). Afferent fibers from the corticopontocerebellar pathway originate in the frontal, parietal, temporal, and occipital lobes of the cerebral cortex, project via the corona radiata and internal capsule to the pontine nuclei. Pontine fibers cross the midline and enter the opposite cerebellar hemisphere as the middle cerebellar peduncle.

Motor control appears to be the primary function of the cerebro-olivocerebellar and cerebroreticulocerebellar pathways. The cerebro-olivocerebellar pathway originates in the frontal, parietal, temporal, and occipital lobes of the cerebral cortex and projects via the corona radiata and internal capsule to the inferior olivary nuclei. Olivary fibers then cross the midline and enter the opposite cerebellar hemisphere through the inferior cerebellar peduncle (Snell, 1997; Voogd, 2003). The cerebroreticulocerebellar pathway originates in the cerebral cortex and projects through the reticular formation, pons, and medulla. From here, the fibers enter the ipsilateral cerebellar hemisphere through the middle and inferior cerebellar peduncles (Schmahmann, 2001; Snell, 1997).

Connections to the Frontal Lobes

Efferent fibers deliver information from the cerebellum to various areas in the central nervous system. Cerebellar output channels include the globose-emboliform-rubral pathway, dentatothalamic pathway, fastigial vestibular pathway, and the fastigial reticular pathway. These pathways have been implicated in motor control and muscle tone (Snell, 1997). Circuits originating from the cerebellum and connecting to cognitive areas of the frontal lobes have also been identified. Research has shown that specific regions of the cerebellum connect to specific areas of the prefrontal cortex. Moreover, there appears to be separate cerebellar circuits that influence motor areas and cognitive areas in the frontal cortex (Dum & Strick, 2003; Middleton & Strick, 1994, 2000, 2001). One such connection is the cerebello-frontal circuit, which connects the cerebellum and the dorsolateral prefrontal cortex. This circuit originates in the lateral cerebellum, projects to the thalamus via the dentate nucleus, and then to the prefrontal cortex, which projects to the pontine nuclei and back to the cerebellum. This loop has been implicated in executive functioning (Heyder, Suchan, & Daum, 2004; Middleton & Strick, 2000).

Recent research has focused on the dentate nucleus in the cerebellum and its connections to the cerebral cortex (Dum & Strick, 2003; Middleton and Strick, 1994, 2001). Circuits originating from the ventral portion of the dentate are connected to several areas within the prefrontal cortex. Specifically, the ventrolateral and ventromedial parts of the dentate nuclei are connected with the prefrontal cortex (Dum & Strick, 2003; Schmahmann, 2001). Research on the cerebellothalamocortical pathway in primates by Middleton and Strick (1994, 2001) found that circuits originating from the ventral dentate in the cerebellum project to the contralateral medial, lateral, and dorsal areas of the prefrontal cortex via the thalamus. Similarly, studies on primates have found that the caudal dentate connects to the rostral and dorsal regions of the frontal lobes (Voogd, 2003). These studies have also demonstrated that the dentate circuits that influence motor function are separate from those that influence cognitive function (Dum & Strick, 2003; Middleton & Strick, 2001). Although much of the literature on cerebellar fiber connections stems from studies on primates, these studies are useful in guiding further understanding of human cerebellar circuitry. Nonetheless, further research on humans is necessary to draw conclusions on the cerebellar-cerebrum connections.

Neuroimaging

Recent neuroimaging procedures have been used to examine these cerebellar-cerebral connections in the human brain. Allen, McColl, et al. (2005) used functional connectivity magnetic resonance imaging (FCMRI) in 12 normal adult participants, ranging from 24-42 years of age in order to examine the connections between the right and left dentate in the cerebellum and other cerebral areas involved in cognition. According to the investigators, "FCMRI is an application of fMRI technology that allows the in vivo examination of coherence in MR signal among functionally related brain regions. It is based on the finding that such regions show correlated low-frequency fluctuations in MR signal during the resting stage" (Allen et al., 2005, p. 40). Both the left and the right dentate showed connectivity with subcortical, parietal, and occipital regions. Of interest to the present study, several regions of connectivity were observed between the right and left dentate and the frontal lobes. In particular, connectivity was observed between the left dentate and areas within the right frontal lobe, such as the superior, medial, and more prominently the middle frontal gyri. Connectivity was also observed between the left dentate and areas within the left hemisphere, specifically the precentral and middle frontal gyri. The right dentate showed connectivity with areas in the frontal lobes, such as the right anterior cingulate gyrus, left cingulate gyrus, and superior and middle frontal gyri. Overall, these cerebellar-cerebral connections provide anatomical support for the cerebellum's involvement in cognitive and executive functions. The connections suggest a functional relationship between the prefrontal cortices, which are involved in higher cognitive functions, and the cerebellum.

EXECUTIVE FUNCTION

Definition

Executive functions are a multidimensional category of cognitive processes. Lezak (1995) described executive functions as the ability to initiate an activity, plan the activity, behave in a goal-directed manner, and monitor one's performance. Similarly, Baron (2004) defines executive functions as:

> metacognitive capacities that allow an individual to perceive stimuli from his or her environment, respond adaptively, flexibly change direction, anticipate future goals, consider consequences, and respond in an integrated or common-sense way, utilizing all these capacities to serve a common purposive goal (p. 135).

As the definitions above indicate, executive functions are not a specific cognitive domain; rather, they consist of a variety of skills and abilities that are employed in order to realize a goal. The conceptualizations of executive functions vary. Generally, the frequently described components of executive functions include concept formation, fluency, inhibition, mental flexibility, planning, and working memory (Anderson, 2001; Baron, 2004; Zillmer & Spiers, 2001).

Concept formation, also referred to as abstract reasoning, is the ability to formulate associations between information or objects that have common features (Anderson, 2001). Concept formation allows one to see beyond simple, concrete concepts and make generalizations (Loring, 1999). Individuals with concept formation deficits are unable to identify similarities between objects or ideas and have difficulty understanding higher-level concepts. Children with poor concept formation might have difficulty reasoning and learning abstract concepts; they often think literally and concretely. An example would be the literal interpretation or misunderstanding of a phrase such as “It is raining cats and dogs.” Tests that evaluate concept formation include the Controlled Oral Word Association, Twenty Questions, Category Test, and Wisconsin Card Sorting Test (Anderson; Spreen & Straus, 1998). Individuals are required to form abstract concepts in order to correctly complete the task.

Fluency is the ability to generate verbal or nonverbal material according to specified rules (Baldo & Shimamura, 1998; Loring, 1999). Individuals with impairments in verbal or nonverbal fluency will have difficulty processing information efficiently (Powell & Voeller, 2004). In the classroom, children with fluency problems might perform poorly on timed tests or have difficulty quickly brainstorming ideas because they cannot process the material in their head in a timely or organized manner. Verbal fluency tasks can be subdivided into phonemic and semantic fluency, which require individuals to produce words that begin with a certain letter or that belong to a certain category, respectively. Phonemic fluency can be assessed by the FAS Test and Controlled Oral Word Association Test (COWAT). Tests reported to assess semantic fluency include Animal fluency, First Name Fluency, and Multilingual Aphasia Examination- Semantic Fluency. Nonverbal fluency tests include the Design Fluency Test, Five-Point Test, and Ruff Figural Fluency Test (Baron, 2004).

Inhibition is the ability to prevent a response or behavior (Baron, 2004). It is also important in the control of attention. Individuals with impaired inhibition display impulsivity, distractibility, and difficulty regulating emotions (Powell & Voeller, 2004). Children with inhibition deficits might be overactive, act without thinking, and have frequent emotional outbursts. In the classroom, children might blurt things out, frequently get out of their seat, or disrupt class activities (Gioia, Isquith, Guy, & Kenworthy, 2000). The Stoop Color-Word Test, Go-No Go Tasks, and Stop Signal Tasks are commonly used assessment tools for inhibition (Baron, 2004). These tests require the person to suppress a prepotent response in order to provide the correct response.

Mental flexibility, also known as set-shifting, is the ability to initiate and change a cognitive set. Individuals with mental flexibility deficits exhibit perseveration, which is inflexibility of thinking or persistence of the same response even when incorrect (Loring, 1999). People who demonstrate perseveration have difficulty transitioning from one activity to another (Powell & Voeller, 2004). Children with shifting deficits ability might spend significant amounts of time thinking about the same topic or might have problems with new situations or changes in routine. Teachers may complain that these children have problems changing from one activity to another or that they demonstrate difficulty changing classes or teachers (Gioia, Isquith, Guy, & Kenworthy, 2000). Tests purported to assess mental flexibility include the Wisconsin Card Sorting Test, Trails B, and Stroop Test (Anderson, 2001). These tests assess the ability to shift from one response to another.

Planning is the ability to formulate and execute strategies in order to complete a task (Baron, 2004) and is comprised of a number of cognitive skills, including organization, problem solving, and reasoning. Individuals with poor planning ability demonstrate disorganization, procrastination, difficulty with challenging tasks, and difficulty with prioritizing (Powell & Voeller, 2004). Children with planning deficits might forget homework at school, forget to turn in assignments, or have difficulty following through on projects (Gioia, Isquith, Guy, & Kenworthy, 2000). Tests that assess planning ability include the Complex Figure of Rey, tower tests, and maze tasks, such as Porteus Mazes.

Working memory is a short-term, limited capacity memory in which information is purposely held, manipulated, and utilized (Baron, 2004; Loring, 1999). Individuals with impaired working memory have difficulty multi-tasking or exhibit forgetfulness because of their inability to keep information in mind (Powell & Voeller, 2004). Parents of children with working memory problems might complain that the child has difficulty remembering things or staying on task. In the classroom, these children have difficulty finishing assignments or concentrating on schoolwork (Gioia, Isquith, Guy, & Kenworthy, 2000). Working memory has been assessed using tower tests (e.g., Tower of Hanoi, Tower of

London, NEPSY Tower, Delis-Kaplan Executive Function System Tower Test), verbal fluency tests (e.g., controlled oral word association test, FAS, animal fluency), span tests (e.g. Letter-Number Sequencing, Digit Span), and the Self-Ordered Pointing Test (Baron). These tests measure the individual's ability to operate on information while it is in memory.

At this time there is not a uniform or unitary conceptualization of executive function; however, concept formation, fluency, inhibition, mental flexibility, planning, and working memory are most often described. Overall, executive functions integrate components of memory, language, sensory, and motor functions so that they result in purposeful, goal-directed behavior (Anderson, 2001; Zillmer & Spiers, 2001). As evident above, there are a large number of tests for executive functions and many of the tests assess more than one component of executive functioning. Given the complexity and multidimensional nature of executive functions, multiple assessment tools are necessary for a thorough evaluation. Although most of these tests were developed for adults, several tests have been adapted and normed for children and adolescents.

Development

The development of executive functions can be explained from psychological and neurobiological perspectives. Research has shown that executive functions develop in a stage-like manner, maturing from childhood to adolescence and into adulthood. In particular, three developmental stages of executive functions have been described. In the first stage, beginning around the age of six, children develop the ability to resist distraction. Secondly, at approximately 10 years of age, children's ability to control impulses, create and test hypotheses, and conduct organized searches of information become similar to adult levels. During the final stage, which occurs in early adolescence, their planning, verbal fluency, and motor sequencing skills reach adult levels (Anderson, 2001; Anderson, Anderson, Northam, Jacobs, & Catroppa, 2001; Brocki & Bohlin, 2004; Welsh, Pennington, & Groisser, 1991). The stage-wise development of executive functions is supported by children's improved performance throughout childhood and into adolescence on measures of executive function, with certain skills developing at different times. In addition, development of executive functions in children also relates to the development of other cognitive abilities, including language, attention, memory, and processing speed (Anderson, 2001).

The functional development of executive functions is related to the neuroanatomical development of several brain structures. Anderson (2001) reported that there is a correspondence between development of executive functions in children and growth spurts in frontal lobe development. The frontal lobes receive input from all cerebral areas, such as the posterior and subcortical regions of the brain; therefore, the maturation of other cerebral areas also improves the functioning of frontal lobes. The development of the brain occurs in a stepwise manner with periods of growth occurring in early infancy, at approximately 7-10 years of age, and then during adolescence, with the frontal cerebral areas maturing relatively later than other brain regions. These growth spurts often correspond to improved performance on neuropsychological measures of executive function, thus providing support for the stage-like development of executive functioning. Interestingly, the development of the cerebellum appears to be interrelated to the development of the frontal lobes. The cerebellum undergoes significant growth during the first years of life and does not reach full maturity until adolescence (Diamond, 2000; ten Donkelaar, Lammens, Wesseling, Thijssen, & Renier, 2003). Moreover, motor development and cognitive development appear to be closely related, with complex skills showing developmental improvements into adolescence (Diamond, 2000). The interrelated development and the anatomical connections between the cerebellum and frontal lobes, discussed below, suggest a functional relationship.

Circuitry of Executive Function

Historically, executive functions have been described as a function solely controlled by the frontal lobes. Studies on adults with lesions in the frontal lobes and the resultant deficits have been used to increase understanding into the functions of this area. Disturbances are found in behavior, affect, and cognitive functioning after lesions to the prefrontal cortex. In particular, a number of executive function impairments are seen when there is damage to the prefrontal cortex (Fuster, 1997). Behavioral and affective problems can include changes in personality, problems with social interaction, aggression, anger outbursts, impulsivity, and hyperactivity. Cognitive problems observed following lesions to the frontal lobes include declines in overall intelligence, attention, memory, language, and academic abilities (Baron, Fennell, & Voeller, 1995).

The frontal lobes can be subdivided into the premotor cortex, the primary motor cortex, and the prefrontal cortex (Powell & Voeller, 2004). The premotor and primary motor cortices are involved in initiating, activating, and performing motor activity. The prefrontal cortex mediates executive functions. The prefrontal cortex can be divided into three regions: the dorsolateral prefrontal cortex, orbitofrontal cortex, and medial prefrontal cortex (Zillmer & Spiers, 2001). The dorsolateral prefrontal cortex, according to Powell and Voeller, "mediates attention and focus, controls distractibility, maintains focus of cognitive set as well as flexible shifts of cognitive set when required, … is involved in memory and generating fluent verbal and nonverbal activity" (pp. 787), and is important in working memory. The orbitofrontal cortex controls social behavior through the mediation of empathy, morality, self-monitoring, and social restraint. The medial prefrontal cortex is involved in motivation, as well as initiation and maintenance of behavior (Powell & Voeller). Thus, the executive control of the prefrontal cortex results in regulation of cognition, behavior, and emotion.

Fronto-Striatal Circuits

Although the frontal lobes serve a vital role in executive functioning, more recent developments have led to the understanding that other cerebral areas also contribute to the mediation of executive functions (Anderson, 2001). Heyder, Suchan, and Daum (2004) reported that fronto-striatal and cerebello-frontal circuits are implicated in the control of executive functions. They described the five major fronto-striatal circuits: the motor, oculomotor, dorsolateral prefrontal, lateral orbitofrontal, and anterior cingulate loops. They indicated that damage to the non-motor circuits (i.e., dorsolateral prefrontal, lateral orbitofrontal, and anterior cingulate loops) could lead to cognitive and behavioral problems; thus, only the connectivity of these circuits will be described. The dorsolateral prefrontal loop starts in the dorsolateral prefrontal cortex, projects through the caudate nucleus to the globus pallidus, which in turn projects through the thalamus and back to the dorsolateral prefrontal cortex. The lateral orbitofrontal loop originates in the orbitofrontal cortex, projects through the caudate nucleus to the globus pallidus, and then through the thalamus back to the orbitofrontal cortex. The anterior cingulate loop begins in the anterior cingulate cortex, projects through the striatum to the globus pallidus, which then projects through the thalamus and back to the anterior cingulate cortex.

It is hypothesized that the functionality of brain structures is disrupted or disabled when there is damage to the circuits that innervate the area (Middleton & Strick, 2000). Research has shown that the dorsolateral prefrontal cortex is involved in initiation and execution of goal-directed behavior, so it follows that the dorsolateral prefrontal circuit is associated with "problem solving, reasoning, concept formation and complex memory tasks that require the self-initiated strategic organization of encoding and retrieval" (Heyder, Suchan, & Daum, 2004, p. 278). Damage to the dorsolateral circuit has been shown to result in attention problems, perseveration, and difficulty completing goals (Powell & Voeller, 2004). The orbitofrontal cortex has been implicated in social adjustment and the control of mood; thus, damage to the lateral orbitofrontal circuit can result in disinhibition, impulsivity, and problems with social behavior. The anterior cingulate is part of the limbic system, which plays a vital role in emotional behavior and motivation (Zillmer & Spiers, 2001), so it follows that patients with damage to the anterior cingulate circuit display amovitation, apathy, poor attention, and flat affect (Powell & Voeller).

Cerebello-Frontal Circuits

As mentioned before, the cerebellum has been implicated in the processing of executive functions. Feedback loops connecting the cerebellum to non-motor areas of the frontal lobes have been identified (Heyder, Suchan, & Daum, 2004; Middleton & Strick, 2000), e.g., the cerebello-frontal circuit connects the dorsolateral prefrontal cortex and the cerebellum. This circuit originates in the lateral cerebellum, projects to the thalamus via the dendate nucleus, and then to the prefrontal cortex, which projects to the pontine nuclei and back to the cerebellum (Heyder, Suchan, and Daum).

Corticopontocerebellar Circuits

Research has demonstrated feedforward loops in the cerebrocerebellar system that are involved in cognition and executive function. The projections originate from the dorsolateral, dorsomedial, and frontopolar areas of the prefrontal cortex and project to the median, paramedian, dorsomedial, and medial parts of the peripeduncular pontine nuclei, which in turn project to the cerebellum (Schmahmann, 2001; Schmahmann & Pandya, 1995; Schmahmann & Pandya, 1997). These corticopontocerebellar projections are different from the cerebello-frontal circuitry described above because they originate in the frontal cortex, whereas the cerebello-frontal circuitry originates in cerebellum. These corticopontocerebellar connections are thought to be an essential part of the anatomic substrate for the cerebellar involvement in executive function (Schmahmann & Pandya, 1995).

Middleton and Strick (2000) hypothesized that damage to regions of the cerebellum that innervate the frontal-cerebellar circuits will result in cognitive deficits that are similar to the deficits seen after damage to prefrontal cortex. Similarly, Schmahmann and colleagues reported that disruption of the neural circuits that link prefrontal and other cerebral cortices with the cerebellum can result in executive function impairments (Schmahmann & Sherman, 1998). These deficits occur because the functionality of the prefrontal cortex is disrupted or disabled as a result of the damage to the circuits. Consistent with these hypotheses, Heyder, Suchan, and Daum (2004) reported a resemblance between the pattern of executive deficits seen in patients with lesions in the prefrontal cortex and patients with lesions in the cerebellum. For instance, lesions to cerebellar areas often result in impairments in planning, problem solving, verbal fluency, and concept formation (Heyder, Suchan, & Daum), cognitive abilities that were thought to be mediated solely by the frontal lobes. Furthermore, Powell and Voeller (2004) indicated that set-shifting and working memory are also impaired when there is damage to the cerebellum. These findings suggest that disruption of the cerebellum can result in damage to circuits involved in executive function.

Functional Neuroimaging

Functional magnetic resonance imaging (fMRI) studies on healthy adults have identified areas of activation within the cerebellum during cognitive processing. For instance, Kim, Ugurbil, and Strick (1994) found bilateral activation of the dentate nucleus in the cerebellum during problem solving. Also, Allen, Buxton, Wong, and Courchesne (1997) determined that posterior portions of the cerebellum are involved in attentional activity. Neuroimaging studies have also implicated the cerebellum in executive functioning in adults.

Garavan, Ross, Li, and Stein (2000) investigated the allocation of attention within working memory in 11 adult participants who ranged in age from 19 to 41 years. The participants were displayed series of large and small squares and were told to keep count of each type of square. All participants underwent fMRI scans during the procedure. The fMRI scans revealed areas of activation in the frontal, temporal, parietal, and occipital lobes. Activation was also evident in subcortical (thalamus, caudate) and cerebellar regions, specifically the left anterior and left posterior lobes of the cerebellum. Overall, the results indicated that many brain areas, including the cerebellum, mediate attentional allocation and working memory. This is consistent with the circuitry of executive functions, which involves several brain structures in the fronto-striatal and cerebello-frontal loops. This further suggests that executive functions are processed throughout several neuroanatomical structures, rather than through a specific brain structure.

Other studies have also had similar findings. Desmond, Gabrieli, Wagner, Ginier, and Glover (1997) investigated cerebellar lobule activation during verbal working memory in a sample of adults. The study consisted of nine adult participants whose average age was 37 years. In the working memory task, the participants were shown a sequence of six random letters on a screen and were instructed to remember the letters within the parentheses. After a five-second delay, a single letter was displayed and participants were to respond if the letter matched any of the previously shown letters within the parentheses. All participants underwent fMRI scans during the procedure. Activation was observed in the right and left cerebellar hemispheres and the posterior vermis during the working memory task. These findings provide further evidence of the cerebellar involvement in executive functions, specifically the process of working memory.

CEREBELLAR PATHOLOGY

Diseases of the Cerebellum

Numerous diseases affect the cerebellum and many of these diseases result in motor and cognitive impairments. Research on cognitive deficits resulting from cerebellar diseases, lesions, and tumors has illustrated the cerebellum's involvement in cognitive functioning. Cerebellar diseases may be developmental or degenerative in nature, or they may be caused by toxic, autoimmune, vascular, or metabolic illnesses (Schmahmann, 2004). Cerebellar pathology often results in motor deficits, such as impairments in fine motor speed, motor coordination, and timing of movement (Gottwald, Wilde, Mihajlovic, & Mehdorn, 2004; Salman, 2002). Often, patients will exhibit a grouping of motor deficits that is termed the "cerebellar motor syndrome". Schmahmann described the cerebellar motor syndrome as consisting of "impairment of gait (ataxia), extremity coordination (dysmetria), disordered eye movements, poor articulation (dysarthria), impaired swallowing (dsyphagia), and tremor. The basic deficit common to the motor activity is impairment of rate, rhythm, and force of contraction" (p. 368).

Cognitive impairments in cerebellar pathology have also been observed. Adults with different types of spinocerebellar ataxias (SCA), a cerebellar degenerative disease, exhibit impairments in executive functions, memory, reasoning, attention, and problems with impulsivity and regulating emotions (Burk, Bosch, et al, 2001; Burk, Globas et al., 2003; Lilja, Hamalainen, Kaitaranta, & Rinne, 2005; Schmahmann, 2004; Steinlin, Styger, & Boltshauser, 1999). Similarly, adults with cerebellar cortical atrophy and olivopontocerebellar atrophy have demonstrated impairments in executive functions and memory (Appollonio, Grafman, Schwartz, Massaquoi, & Hallet, 1993; Grafman et al., 1992). Adults with Friedreich ataxia, an autosomal-recessive degenerative disease, display impaired speed of information processing, visual-spatial abilities, verbal memory, and the executive function components of set-shifting and verbal fluency (Corben et al., 2006). Children with congenital nonprogressive cerebellar ataxia also demonstrate impaired nonverbal abilities, attention, and executive functions (Steinlin et al., 1999). However, other patients with cerebellar atrophy have not been shown to exhibit cognitive deficits (Globas et al., 2003; Tanaka, Harada, Arai, & Hirata, 2003). In terms of executive functions, patients with cerebellar degenerative diseases have been shown to exhibit impaired verbal fluency, planning, set-shifting, and concept formation (Burk, Bosch, et al.; Burk, Globas, et al.; Globas et al., 2003; Corben et al.; Grafman et al.; Lilja et al, 2005).

Cerebellar Cognitive Affective Syndrome

According to Schmahmann (2004), patients with cerebellar lesions resulting from stroke, infection, atrophy, and tumor often display behavioral changes, which he and his colleagues termed the "cerebellar cognitive affective syndrome". The author indicated that the cerebellar cognitive affective syndrome is characterized by:

1) disturbances of executive function, which includes deficient planning, set-shifting, abstract reasoning, working memory, and decreased verbal fluency;
2) impaired spatial cognition, including visual-spatial disorganization and impaired visual-spatial memory;
3) personality change characterized by flattening or blunting of affect and disinhibited or inappropriate behavior; and
4) linguistic difficulties, including dysprosodia, agrammatism and mild anomia. The net effect of these disturbances in cognitive functioning [is] a general lowering of overall intellectual function (p.371).

The cognitive and affective disturbances seen after cerebellar lesions lend support to the non-motor functions of the cerebellum.

Schmahmann (2004) reports that the cerebellar cognitive affective syndrome has been documented in children with different diseases affecting the cerebellum. Children with developmental anomalies, such as nonprogressive cerebellar ataxia and complete and partial agenesis of the cerebellum, demonstrate motor, cognitive, and psychiatric impairments. In addition, children with developmental anomalies of the cerebellum can have executive deficits, such as poor verbal fluency, working memory, abstract reasoning, as well as perseveration and disinhibition.

The cerebellar cognitive affective syndrome has also been reported in children surgically treated for cerebellar tumors. Levisohn, Cronin-Golomb, and Schmahmann (2000) found that children who had undergone surgical resection of cerebellar tumors exhibited impaired executive functions, visual-spatial abilities, verbal memory, and expressive language abilities. Moreover, these children demonstrated problems with regulation of emotions and behavior. Similarly, Ronning, Sundet, Tonnessen, Lundar, and Helseth (2005) found that children treated for cerebellar tumors had impairments in attention, motor speed, and executive functions. Riva and Giorgi (2000) also found irritability and executive function, attention, and language impairments in children with surgically resected cerebellar tumors. A more detailed discussion of cognitive functioning in children with resection of cerebellar tumors can be found in the posterior fossa tumors section of the literature review.

Cerebellar Lesions

A variety of cognitive deficits are seen in patients with cerebellar lesions resulting from infarcts, hematoma, edema, and tumor. As previously mentioned, insults to the cerebellum result in damage to circuits that mediate cognitive functions. These patients exhibit memory deficits, such as impaired verbal memory, visual memory, episodic memory, and working memory (Exner, Weniger, & Irle, 2004; Gottwald, Wilde, Mihajlovic, & Mehdorn, 2004; Malm et al., 1998). Some studies have shown that patients with cerebellar lesions have impaired visual-spatial abilities (Kalashnikova, Zueva, Pugacheva, & Korsakova, 2005; Malm et al.; Molinari, Petrosini, Misciagna, & Leggio, 2004), whereas other studies have failed to find visual-spatial deficits (Gottwald et al., 2004). Attention difficulties are also commonly found in these patients (Akshoomoff & Courchesne, 1992; Courchesne et al., 1994; Exner et al., 2004; Gottwald et al; Kalashnikova et al., 2005; Malm et al.; Townsend et al., 1999). In addition to cognitive impairments, studies have shown that both adult and child patients with cerebellar lesions exhibit behavioral and affective disturbances (Exner et al.; Gottwald et al.; Richter et al, 2005). Despite the cognitive, behavioral, and affective changes caused by cerebellar lesions, intelligence does not appear to be affected (Gottwald et al.; Malm et al.).

In addition to the cognitive deficits described above, several studies have demonstrated impairments in some executive functions in adult patients with cerebellar lesions. Gottwald, Wilde, Mihajlovic, and Mehdorn (2004) investigated the role of the cerebellum in higher cognitive processes and the role of lesion location on the profile of deficits in an adult sample. Twenty-one adult participants, ranging in age from 26 to 71 years, with focal cerebellar lesions resulting from hematoma, edema, or tumor, participated in the study. The control sample consisted of 21 healthy adult participants, ranging in age from 27 to 75 years, who were matched for age, gender, and years of education. The study was conducted in Germany and participants were administered tests in their German version. A battery of neuropsychological tests was administered to assess several cognitive domains; for the purpose of the current study, only those tests that focused on executive functions will be described. Executive functions were assessed using semantic and phonemic verbal fluency, figural fluency (Five Point Test), motor flexibility (Hand Movements, K-ABC, German version), Modified Card Sorting Test (MCST), Stroop (German version), and Similarities on the Weschsler Adult Intelligence Test- Revised (WAIS-R, German version). Results showed that semantic, phonemic verbal, and figural fluency were significantly worse than controls. Impairments were also seen on Similarities and Hand Movements. Moreover, patients scored significantly worse than controls on the verbal speed (Color Word Reading and Color Naming) component of the Stroop. On the Trailmaking Test, patients performed significantly worse on both Part A and B; the difference between both of these parts of the test was also significant. Interestingly, Gottwald et al. (2004) stated that, "the patient subgroup with right-sided lesions showed deficits in almost all the tests that had proved to be significant in the wider group . . . [whereas] patients with left-sided lesions showed only very few significant differences compared to their control group" (p. 1528).

Overall, Gottwald, Wilde, Mihajlovic, and Mehdorn (2004) found that patients with focal cerebellar lesions have a variety of cognitive impairments. In regards to executive functions, patients demonstrated impaired verbal and figural fluency, working memory, verbal concept formation, mental flexibility, and motor flexibility. However, no significant differences were found in the Modified Card Sorting Test, which measures mental flexibility and concept formation, or in the interference portion of the Stroop Test, which assesses inhibition. The results of the study indicate that lesions to the cerebellum result in variable impairments in executive functions. Future research could improve upon this study by examining homogeneous cerebellar lesion populations in order to avoid the inherent differences in treatment and prognosis when using heterogeneous groups (e.g., hematoma, edema, or tumor in the cerebellum); assessing whether similar results are found in a pediatric population with focal cerebellar lesions; and using a US sample in order to improve generalizability to an English-speaking population. The current study addressed these limitations by using a multidimensional assessment of executive functions in a homogeneous group of children treated for cerebellar tumors.

Further support for a cerebellar role in executive functioning is gained from the research conducted by Malm et al. (1998), who investigated cognitive impairments and functional outcome in adult patients with infratentorial infarcts in Sweden. The study consisted of 24 adult patients, ages 18 through 44, with isolated cerebellar or brainstem strokes. The control group consisted of 14 healthy participants matched for age. A neuropsychological battery was administered at intake, four months, and 12 months; however, only the results of the first evaluation were reported in the article. Tests assessing working memory (a sentence span task, a word span task, and Digit Span from the WAIS-R), verbal fluency (Controlled Oral Word Association Test), and cognitive flexibility (Trail Making Test) were administered as part of the neuropsychological battery. Results showed that patients performed significantly worse than controls on the working memory span tasks. No significant difference was found in verbal fluency (Controlled Oral Word Association Test). Patients performed significantly worse on the Trail Making Test part A, but were within normal limits on part B. No information was provided regarding lateralization of function in the cerebellar hemispheres; however, results showed a significant correlation between the size of the lesion and verbal as well as performance IQ. Overall, the study found few executive function deficits, with impairments only seen in working memory; no deficits were seen in verbal fluency or cognitive flexibility. These findings are inconsistent with other studies on cerebellar lesions (e.g., Gottwald, Wilde, Mihajlovic, & Mehdorn, 2004), which have reported executive function deficits consisting of verbal fluency and mental flexibility. This study was limited by the use of a heterogeneous group of infratentorial infarct patients, which included both cerebellar and brainstem lesions.

Exner, Weniger, and Irle (2004) investigated executive functions in adult patients with focal cerebellar infarctions. The study consisted of six patients with infarctions in the posterior inferior cerebellar artery (PICA) area, five clinical control subjects with infarctions in the superior cerebellar artery (SCA) area, and 11 matched healthy controls. The study was conducted in Germany. All participants received a neurological, psychiatric, and neuropsychological examination. Of interest to the current project, the participants were administered the Trail-Making Test and the Stroop. Results demonstrated that PICA patients scored significantly below healthy control on the measures of attention (Trail-Making Test-Part A and Stroop- Reading) and mental flexibility (Trail-Making Test- Part B); however, no significant differences were found on the interference task of the Stroop. SCA patients scored significantly worse than healthy controls on visual-spatial working memory (Wechsler Memory Scale: Visual Memory Span, backward). Overall, patients with infarctions to the posterior inferior area of the cerebellum displayed impaired attention and mental flexibility, whereas patients with infarctions to the superior region of the cerebellum displayed impaired visual-spatial working memory. No impairments in inhibition were found. Interestingly, while the studies on cerebellar lesions conducted by Exner et al. and Gottwald, Wilde, Mihajlovic, & Mehdorn (2004) found executive function deficits in mental flexibility, Malm et al. (1998) found this cognitive ability to be intact. Limitations in the Exner et al. study included a small sample size (n = 11 in study group) and a limited assessment of executive functions. Given the multidimensional nature of executive functions, more comprehensive measures are necessary to provide a better understanding of the executive function deficits in patients with cerebellar lesions.

Overall, studies on adult patients with cerebellar lesions have found impaired cognitive functioning. In particular, they have demonstrated a variety of executive function deficits. While some studies have found verbal fluency, concept formation, and mental flexibility deficits, other studies have found these components of executive functions to be intact. Working memory deficits have consistently been found; however, no impairment in inhibition was found in the studies above. Although the results of the studies indicate that lesions to the cerebellum can result in impaired executive functions, no conclusive results have been found. Limitations in the cerebellar lesion studies include the use of heterogeneous cerebellar lesion populations consisting only of adults, limited assessment of executive functions, and small sample sizes. The current study addressed these limitations by using a comprehensive, multidimensional assessment of executive functions in a homogeneous group consisting only of pediatric patients treated for cerebellar astrocytomas.

Posterior Fossa Tumors

Consistent with research on adults, studies on pediatric patients with cerebellar lesions have also found high rates of cognitive deficits. The majority of research on children with lesions in the cerebellum is derived from studies on pediatric posterior fossa tumors. The posterior fossa is the area near the base of the skull where the cerebellum and brain stem are located. Common types of posterior fossa tumors include brainstem glioma, cerebellar astrocytoma, choroid plexus papilloma, ependymoma, hemangioblastoma, medulloblastoma, and primary neuroectodermal tumors. Many of the studies conducted on posterior fossa tumors have included heterogeneous groups of tumor types and varying combinations of treatment modalities. Treatments for children with posterior fossa tumors, which account for approximately two thirds of the brain tumors in children (George et al., 2003), typically consist of surgery, radiation, and chemotherapy.

Radiation and Chemotherapy

The effects of cranial radiation and chemotherapy on cognitive functioning in children treated for posterior fossa tumors are well known. Deficits are widespread and include impaired verbal and nonverbal intelligence, verbal and visual memory, working memory, attention, visual-spatial abilities, executive functions, language, and academic skills (George et al., 2003; Konczak, Schoch, Dimitrova, Gizewski, & Timmann, 2005; LeBaron, Zeltzer, Zeltzer, Scott, & Marlin, 1988; Maddrey et al., 2005). These deficits are a result of the neurotoxic effects of radiation and chemotherapy, which cause damage to white matter and other brain structures (American Cancer Society, 2005; Mabbott, Noseworthy, Bouffet, Rockel, & Laughlin, 2006).

George et al. (2003) investigated memory and intellectual functioning in children treated with surgery, radiation, and chemotherapy for medulloblastoma and cerebellar astrocytoma. They conducted a retrospective review of 15 children with posterior fossa tumors (11 with medulloblastoma and four with cerebellar astrocytoma), ages six to 17 years, who had cranial irradiation following surgical resection of the tumor and who had been administered all or sections of the Wechsler Scales of Intelligence and the Wide Range Assessment of Memory and Learning. Children who had received chemotherapy (other than methotrexate), in addition to the surgery and radiation, were also included in the study. The investigators reported that patients who received methotrexate were excluded because research has shown that this type of chemotherapy has been associated with neurocogntive deficits. Results indicated that Full Scale, Verbal, and Performance IQ were significantly lower than normative population on the Wechsler Scales of Intelligence. Verbal, Visual, and General Memory Indexes on the WRAML were also significantly lower than the normative population. The differences between verbal and nonverbal IQ means, as well as between Verbal and Visual Memory Indices, were not statistically significant. A stepwise multiple regression analysis determined that age at diagnosis accounted for a significant portion of variability in Full Scale IQ (61%), Verbal IQ (67%), and Performance IQ (45%). In addition, children less than six years of age at diagnosis had significantly lower VIQ, PIQ, and FSIQ than children age six years and older at diagnosis.

Overall, the results from the study conducted by George et al. (2003) found that children treated for medulloblastoma and cerebellar astrocytoma with surgery, radiation, and chemotherapy have significantly lower performance on measures of intelligence and memory. Specifically, they demonstrate weaker Full Scale, verbal, and nonverbal intelligence. They also exhibit significant weaknesses in verbal, visual, and overall memory.

Furthermore, the results indicated that children diagnosed at younger ages were at a significantly higher risk of having intellectual deficits. Limitations of the study are its relatively small sample size, the heterogeneous sample of tumor and treatment types, the use of a retrospective research design, and limited assessment of cognitive functions. The small sample size (n = 15) limits the strength of the statistical analyses and reduces the generalizability to other types of posterior fossa tumors patients. Similarly, the heterogeneous sample of tumor and treatment types is also a limitation because the differences in treatments, medications, and growth of each tumor type restrict generalizability to all tumors. The use of a retrospective research design reduces the degree of control over the variables assessed. Consequently, the study is also limited in its assessment of cognitive functions and lacks assessment of executive functions.

Other studies have also found cognitive impairments in patients treated with radiation and chemotherapy for posterior fossa tumors. Konczak, Schoch, Dimitrova, Gizewski, and Timmann (2005) examined working memory in children and adults with posterior fossa tumors in order to determine whether age at surgery and surgical site affected recovery. Twenty-two patients, ages 11 through 28 years, with surgical removal of posterior fossa tumors (medulloblastoma, astrocytoma, cavernoma, ependymoma, and plexuspapilloma) were divided into three groups: 1) the early childhood group consisted of patients who had surgery within the first four years of life; 2) the middle childhood group consisted of patients who had surgery between the ages of six and nine years; and 3) the adolescent group consisted of patients who had surgery between the ages of 12 and 17 years. Some of the children were also treated with radiation and chemotherapy. Visual-spatial working memory was assessed using Corsi's block tapping task. Verbal working memory was assessed using the forward and backward digit span on the WISC-IV. No significant differences were found in the patients' performance on digit span and between forward and backward digit span. Results found that the subgroup of patients who received radiation and/or chemotherapy had significantly poorer performance on Corsi's block tapping task. Age at surgery, lesion volume, or time since surgery were found to be poor predictors of recovery for cognitive and motor functions. Overall, Konczak et al (2005) found no verbal working memory deficits in patients treated with surgery; however, posterior fossa tumor patients who were treated with combinations of radiation and chemotherapy exhibited visual span memory deficits.

Cranial radiation and chemotherapy can have toxic effects on the brain. Overall, patients treated for posterior fossa tumors with radiation and chemotherapy demonstrate declines in Full Scale, Verbal, and Performance IQ's. These patients also exhibit impairments in verbal, visual, and general memory. Verbal working memory does not appear to be negatively impacted in the studies above; however children treated with combinations of radiation and chemotherapy demonstrated impaired visual span memory. Inconclusive results have been found in regards to the effect of age at diagnosis on outcome. The studies described above have a number of limitations, such as the use of retrospective research designs, which limit control over the cognitive domains assessed and the measures used. Furthermore, the small sample sizes limit the strength of the statistical analyses and also reduce the generalizability of the findings to the population of posterior fossa tumor patients. Similarly, the studies are limited by the use of groups consisting of mixed tumor and treatment types. Given that tumors differ in growth rate and response to treatment modalities (surgery, chemotherapy, and radiation), the use of heterogeneous groups limits the generalizability of results to all posterior fossa tumors as well as the ability to identify deficits specific to each posterior fossa tumor type. Furthermore, the studies are limited in their assessments of cognitive abilities and executive functions. In order to address the limitations of these studies, the current study employed a prospective research design utilizing a multidimensional, comprehensive assessment of executive functions in a large homogeneous group of children treated for cerebellar tumors.

Surgery

The negative effects of radiation and chemotherapy on cognitive functioning are recognized. Similar cognitive disturbances are also seen in pediatric patients with surgical excisions of posterior fossa tumors. While some studies on pediatric patients treated with surgical resection of posterior fossa tumors show no declines in full scale, verbal, and nonverbal intelligence (Karatekin, Lazareff, & Asarnow, 2000), other studies demonstrate deficits in these intellectual domains (Beebe et al., 2005; Steinlin et al., 2003). Impaired memory functions are found in young patients treated with surgery for posterior fossa tumors (Aarsen, Van Dongen, Paquier, Van Mourik, & Cateman-Berrevoets, 2004; Ater et al., 1996; Levisohn, Cronin-Golomb, & Schmahmann, 2000; Riva & Giorgi, 2000; Steinlin et al.). In addition, language deficits are seen in posterior fossa tumor patients treated with surgery (Levisohn et al., 2000; Aarsen et al., 2004; Riva & Giorgi).

Other cognitive impairments have also been found in children treated for posterior fossa tumors. Most studies have demonstrated visual-spatial and visual-motor deficits in children treated with surgery for posterior fossa tumors (Aarsen, Van Dongen, Paquier, Van Mourik, & Cateman-Berrevoets, 2004; Levisohn, Cronin-Golomb, & Schmahmann, 2000; Steinlin et al., 2003); however, some studies have failed to replicate these findings (Ater et al, 1996). Impaired attention (Aarsen et al., 2004; Riva & Giorgi; Steinlin et al.) and decreased processing speed (Steinlin et al.) have also been noted in patients with surgical resection of posterior fossa tumors.

Overall, patients who have undergone solely surgical resection of posterior fossa tumors typically are thought to have a better prognosis than patients who have received chemotherapy and radiation. However, cognitive deficits are still found in this population. Children with surgical excision of posterior fossa tumors have impairments in memory, language, attention, and processing speed. Mixed results have been found in regards to impaired intelligence, visual-spatial skills, and visual-motor skills. Furthermore, inconsistent evidence has been found for executive function deficits in pediatric patients surgically treated for posterior fossa tumors.

Executive Functions in Posterior Fossa Tumors

An unanswered question is whether executive function deficits are present following surgical resection of posterior fossa tumors, specifically cerebellar tumors. Although executive functions are sometimes found problematic in children surgically treated for cerebellar tumors; however, results from research have been inconclusive. Consistent with research on cerebellar lesions, surgical treatment for cerebellar tumors appears to damage the circuits involved in executive functions, such as the cerebello-frontal circuit (Middleton &

Strick, 2000; Heyder, Suchan, & Daum, 2004). Several studies have examined executive functioning in groups of heterogeneous posterior fossa tumors. Steinlin et al. (2003) investigated the long-term neuropsychological effects of treatment for different posterior fossa tumors in patients. They examined 24 children and adults, ages 7 through 26 years, who had undergone surgical resection of a posterior fossa tumor with no radiation or chemotherapy treatment. The sample was comprised of a heterogeneous group of posterior fossa tumors: cerebellar pilocytic astrocytoma, choroid plexus papilloma from the fourth ventricle, astrocytoma grade II, gangliocytoma, and hemangioblastoma. Age at diagnosis/operation ranged from 3.6 to 15.5 years. Various cognitive domains were assessed in the study; however, only the results of the testing on executive functions will be reviewed. Executive functions were assessed using Verbal fluency, Stroop test, Design fluency, and Similarities subtest from the Hamburg-Wechsler Intelligence Scales for Children/Adults (HAWIK-R/HAWIE-R; the German version of the Wechsler Intelligence Scales). Results showed significantly lower performance on Verbal fluency and all three subtests on the Stroop. In terms of localization, results suggested that the left cerebellar hemispheres were important in processing executive functions. Overall, the study found that adult and child patients surgically treated for posterior fossa tumors have verbal fluency and inhibition deficits; however, design fluency and concept formation were intact. Strengths of the study include the use of both adults and children in the sample and a wide-range assessment of cognitive abilities, including executive functions; however, a limitation of the study includes the use of a sample with heterogeneous tumor types. Moreover, many of the studies on posterior fossa tumors have been conducted in foreign countries and with measures normed on foreign populations, which limit generalizability to an English-speaking population.

In order to determine whether cognitive functioning is affected by lesions to the cerebellum and whether the lesion site results in varying deficits, Riva and Giorgi (2000) examined patients who underwent surgical resection for cerebellar astrocytoma or cerebellar vermis medulloblastoma. The sample consisted of 26 pediatric patients who ranged in age from seven to 12.6 years in the astrocytoma group and six to 12.1 years in the medulloblastoma group. The following measures of executive functions were used as part of a more comprehensive neuropsychological battery: Wisconsin Card Sorting Task (WCST), Verbal Fluency, and Design Fluency. All tests were administered in their Italian version. Results demonstrated that patients who had right hemisphere cerebellar astrocytomas had significantly poorer performance on the WCST and Verbal Fluency, whereas patients with left hemisphere cerebellar astrocytoma only had significantly poorer performance on the WCST. In order to analyze the results, patients with cerebellar vermis medulloblastomas were divided into two groups: group 1 consisted of children with mutism and no behavioral disturbance (n = 6) and group 2 consisted of children with behavioral disturbances plus neuropsychological deficits (n = 5). Within the mutism group (group 1), children who had subsequent speech disturbances (n = 4) had significantly poorer performance on Verbal fluency, and children who had subsequent language disturbance (n = 2) had significantly poorer performance on Design fluency and Verbal fluency. Within the behavioral disturbance group (group 2, n = 4), all but one patient performed within normal limits. Overall, patients with left hemisphere cerebellar astrocytomas had concept formation and mental flexibility deficits; in addition to these deficits, patients with right hemisphere cerebellar astrocytomas also exhibited poor verbal fluency. In general, subgroups of patients with cerebellar vermis medulloblastoma and mutism displayed impaired verbal and design fluency. Given the multiple variables that the study examined, a limitation to the study is its sample size. Additionally, generalizability to an English-speaking population is limited.

Although several studies have found executive function deficits in patients with posterior fossa tumors, other studies have found intact executive functions in these patients. As part of a larger study, Ater et al. (1996) investigated executive functions in a group of children who had undergone surgical resection of astrocytoma tumors in the posterior fossa. Participants received neuropsychological assessments within three months of diagnosis. Although the battery assessed various cognitive domains, only executive functioning will be discussed. Executive functions were assessed using the Trail Making Test parts A and B and the Freedom from Distractibility Deviation Quotient (FDDQ) from the Wechsler Intelligence Scale for Children- Revised. Results showed that patients who had astrocytomas in the posterior fossa did not exhibit impaired executive functioning. The results from the study refute most research findings that patients treated for posterior fossa tumors exhibit some executive function deficits. The lack of findings may be due to the very limited assessment of executive functions. Given that executive functions are multidimensional, a single test is not sufficient in identifying deficits.

As shown, a small number of studies have focused on executive functions in posterior fossa tumor patients; however, findings have been inconclusive on the presence and level of impairment. Results have shown that these patients exhibit impaired verbal and design fluency, inhibition, concept formation, and mental flexibility. Yet, other studies have shown design fluency, concept formation, and mental flexibility to be within normal limits. The inconclusive nature of executive function impairment in surgically resected posterior fossa tumor patients is consistent with the inconclusive findings in adult cerebellar lesion patients described above. Some adult cerebellar lesion studies have found verbal fluency, concept formation, and mental flexibility deficits, while other studies have found these components of executive functions to be intact. Deficits have consistently been found in working memory, but few studies have reported impairment in inhibition (Exner et al., 2004; Gottwald, Wilde, Mihajlovic, & Mehdorn, 2004; Malm et al., 1998). In general, no conclusive results have been found regarding executive function impairment in patients with surgically resected posterior fossa tumors.

Although the studies on surgically resected posterior fossa tumors are not confounded by the neurotoxic effects of radiation and chemotherapy, these studies have some weaknesses. For example, the studies have heterogeneous tumor types, small sample sizes, and limited assessment of executive functions. As mentioned before, these weaknesses can limit the generalizability of the results to other posterior fossa tumor patients. The current study attempted to improve upon these studies by assessing a sample of surgically treated cerebellar astrocytoma patients using a wide-range of executive function tasks. While a few studies have focused on executive functioning in homogeneous groups of cerebellar tumors, those that exist still demonstrate a number of limitations.

Cerebellar Pilocytic Astrocytomas

CPA are a type of posterior fossa tumor that occupies the same region as the other posterior fossa tumors described above, but they are not typically treated with chemotherapy and radiation. A small number of studies have investigated executive functioning in homogeneous groups of CPA. Although these studies are not confounded by mixed treatment or tumor types, they still have several limitations.

CPA constitute approximately 10-20% of all childhood brain tumors (Hildebrand, & Baleriaux, 2002) and 30-40% of all posterior fossa tumors (Packer, Friedman, Kun, & Fuller, 2002), thus making them the second most common cerebellar tumor in children. They occur mostly in the first decade of life; however, there is another peak in the early part of the second decade. Cerebellar astrocytomas can be found in both cerebellar hemispheres, the vermis, and occasionally within the cavity of the fourth ventricle (Cohen & Duffner, 1994). Typically, cerebellar astrocytomas are cystic, meaning that the are comprised of fluid surrounded by a membrane; these types are more commonly located in the cerebellar hemispheres. Solid tumor types are found more often in the vermis (Cohen & Duffner). The tumors can range from benign juvenile pilocytic astrocytomas to higher-grade glioblastomas (Hildebrand & Baleriaux); however, CPA account for 80-85% of cerebellar astrocytomas (Cohen & Duffner).

Children experiencing acute symptoms of cerebellar astrocytomas typically present with headaches and vomiting, which are results of increased intracranial pressure. Disturbances in gait are also common. CT or MRI scans are used to identify the tumor

(Cohen & Duffner, 1994). Complete surgical resection of the tumor is frequently the recommended treatment for cerebellar astrocytomas (Hildebrand, & Baleriaux, 2002). Recurrence of the tumor is uncommon and approximately 90-95% of children require no further treatment after surgery (Cohen & Duffner). Additional radiation and/or chemotherapy are often unnecessary for children with total resection of the tumor (Packer, Friedman, Kun, & Fuller, 2002). More invasive, higher-grade cerebellar astrocytomas may be treated with radiation and/or chemotherapy; however, their effectiveness in these types of tumors appears to be questionable (Hildebrand, & Baleriaux).

Cerebellar astrocytomas are considered to have the best medical prognosis of any intracranial tumor in childhood (Cohen & Duffner, 1994; Hildebrand & Baleriaux, 2002). As a result of the treatment modality (surgical excision of tumor with no cranial radiation or chemotherapy) and good medical prognosis, children treated for cerebellar astrocytomas are thought to have minimal cognitive impairment. However, children treated for cerebellar astrocytomas have been shown to display a variety of cognitive deficits, including inconsistent impairments in executive functions (Aarsen, Van Dongen, Paquier, Van Mourik, & Catsman-Berrevoets, 2004; Beebe et al., 2005; Karatekin, Lazareff, & Asarnow, 2000).

Executive Functions in Cerebellar Pilocytic Astrocytomas

Few studies have investigated executive functions in childhood survivors of CPA. The studies that exist have improved upon research on executive functions in children treated for posterior fossa tumors by eliminating mixed tumor types and treatment modalities.

However, studies on executive functions in children treated for CPA demonstrate a number of limitations, such as small sample sizes and limited assessment of executive functions.

A study conducted by Karatekin, Lazareff, and Asarnow (2000) examined the effect of surgical resection of cerebellar astrocytomas on executive functions and compared the results to patients who had temporal tumors or cysts. The study group consisted of only four pediatric patients, ages eight through 13 years, who had undergone excision of hemispheric cerebellar astrocytomas and did not have radiation or chemotherapy. The comparison group consisted of six patients, ages 8 through 21, who were treated for temporal tumors or cysts (astrocytoma, arachnoid cyst, craniopharyngioma). Patients were administered the Wechsler Adult Intelligence Scale- Revised (WAIS-R) or the Wechsler Intelligence Scale for Children, Third Edition (WISC-III) depending on the patient's age, and the computerized version of the Wisconsin Card Sorting Task (WCST). Time from surgery to testing ranged from six to 119 months in the cerebellar tumor group and less than one month to 22 months in the temporal group. Differences of one to two standard deviations between WCST and FSIQ were considered a trend; statistical significance was obtained if the difference was greater than two standard deviations. Results from intelligence testing indicated that Full Scale IQ (FSIQ) scores ranged from average to high average; no significant differences were found between the cerebellar and temporal groups in terms of FSIQ. Results from executive function testing showed that the cerebellar patients scored in the borderline to low average range, with 75% of cerebellar patients (three out of four patients) exhibiting a trend toward poor performance on the WCST. The z-score difference between the WCST and IQ ranged from 1.5 to 1.77 for these three cerebellar patients. One out of the six patients in the temporal group exhibited a trend toward poor performance on the WCST compared to IQ. Given that parents did not report executive function difficulties during clinical interviews, Karatekin et al. speculated that, "the normal IQs of these children, especially their intact verbal skills, may have been masking deficits in executive function" (p. 111). Overall, the study found no significant differences in terms of intelligence or executive functions. However, the cerebellar tumor patients exhibited a trend for weaker performance in the areas of concept formation and mental flexibility. Although the study investigated executive function in a homogeneous sample of patients with cerebellar tumors, limitations of the study included an extremely small sample size (n = 4) and a limited assessment of executive function consisting only of the Wisconsin Card Sorting Task.

Further support for the cerebellum's role in executive functioning comes from the following study, which also consists of a homogeneous group of CPA. Aarsen, Van Dongen, Paquier, Van Mourik, and Cateman-Berrevoets (2004) investigated neurological, neuropsychological, and behavioral functioning in cerebellar astrocytoma patients. The study consisted of 26 child and adult patients, ages six to 22 years, surgically treated for cerebellar astrocytomas with no radiation or chemotherapy in the Netherlands. The neuropsychological battery assessed several cognitive domains; however, only the results of executive function tasks will be reported. Executive functions were assessed using the Trailmaking Test (TMT), Verbal Fluency, Wisconsin Modified Card Sorting Test (WMCST), and Mazes on the Wechsler Intelligence Scale for Children- Revised (WISC-R Mazes). All tests were administered in Dutch. According to results, participants had significantly weaker performances in comparison to norms on the WMCST. No significant differences were found between groups with a surgical incision in the left or right hemisphere or the vermis. Significant correlations were found between tumor diameter and executive functions (WMCST categories). Analyses indicated that 17% of patients obtained Z scores of less than -2 on WMCST categories. Interestingly, the investigators reported that 24% of participants required special education services, thus reflecting the severity of their neurocognitive impairments. Overall, the results from the study showed impaired mental flexibility and concept formation. No impairments were found in verbal fluency and planning; a separate measure of mental flexibility was found to be within normal limits. Strengths of the study include a relatively larger, homogeneous sample of tumor patients. Given that the testing was conducted in Dutch, the generalizability of the results to an English-speaking population is somewhat limited.

Very few studies exist on executive functioning in patients with cerebellar astrocytomas. The studies that have been conducted have mixed results on the presence of executive function deficits. The limitations of these studies are similar to those of the other posterior fossa tumor studies. Limitations include small sample sizes, limited assessment of executive functions, and uncertain generalizability due to language differences. The current study attempted to address all these issues and improve upon the previous studies by administering a comprehensive, multidimensional evaluation of executive function to a homogeneous group of children treated for cerebellar astrocytomas.

Recent research indicates that the cerebellum is involved in cognitive functioning. In particular, the cerebellum reportedly plays a role in executive functioning. Much information regarding executive function is obtained from patients with posterior fossa tumors. However, studies have found mixed results regarding the presence or level of executive function impairment in posterior fossa tumors. Many of the studies conducted on posterior fossa tumors have included patients treated with chemotherapy or radiation, treatments which have consistently been shown to have neurotoxic effects. The few studies that have utilized patients with surgical resection of posterior fossa tumors have consisted of heterogeneous tumor types. Even fewer studies have been conducted on samples with homogeneous tumor and treatment. Results of the posterior fossa studies have shown that some patients exhibit impaired verbal and design fluency, inhibition, concept formation, and mental flexibility. Yet other studies show that these executive functions are not significantly impaired. To date, there are no conclusive results on the level of executive function impairment in cerebellar tumor patients. A study addressing the limitations of past research is needed in order to clarify the level of executive function impairment.

SUMMARY

Significant improvement in rate of cancer survivorship has led to an increased focus on the morbidity of cancer treatment in terms of cognitive and behavioral functioning. Treatments for children with posterior fossa tumors, which account for approximately two thirds of the brain tumors in children (George et al., 2003), typically consist of surgery, radiation, and chemotherapy. The effects of cranial radiation and chemotherapy on cognitive functioning in children treated for posterior fossa tumors are well known. Deficits are widespread and include impaired overall, verbal, and nonverbal intelligence, verbal and visual memory, working memory, attention, visual-spatial abilities, executive functions, language, and academic skills (George et al., 2003; Konczak, Schoch, Dimitrova, Gizewski, & Timmann, 2005; LeBaron, Zeltzer, Zeltzer, Scott, & Marlin, 1988; Maddrey et al., 2005). These deficits are due to the neurotoxic effects of radiation and chemotherapy, which result in damage to white matter and other brain structures (American Cancer Society, 2005; Mabbott, Noseworthy, Bouffet, Rockel, & Laughlin, 2006).

Research also suggests that a number of cognitive deficits exist in children following surgical resection of posterior fossa tumors. Impaired memory, language, attention, and processing speed have consistently been noted in children surgically treated for posterior fossa tumors (Aarsen, Van Dongen, Paquier, Van Mourik, & Cateman-Berrevoets, 2004; Ater et al., 1996; Levisohn, Cronin-Golomb, & Schmahmann, 2000; Riva & Giorgi, 2000; Steinlin et al., 2003). Mixed results have been found for intelligence and visual-spatial abilities (Beebe et al., 2005; Steinlin et al.; Karatekin, Lazareff, & Asarnow, 2000; Aarsen et al., 2004; Levisohn et al., 2000; Steinlin et al.; Ater et al.). However, these studies group a number of heterogeneous tumor types within the posterior fossa and rarely identify the cognitive effects that are associated with surgery for each type of tumor. Also, many of these studies have been conducted in foreign countries with tests and/or norms specific to that country.

An unanswered question is whether executive function deficits are present following surgical resection of posterior fossa tumors. Executive functions are multidimensional cognitive processes that are involved in goal-directed activity and include cognitive flexibility, fluency, inhibition, problem solving, concept formation, planning, and working memory (Anderson, 2001; Baron, 2004; Zillmer & Spiers, 2001). Executive functions are sometimes found problematic in children surgically treated for posterior fossa tumors; however, results from research have been inconclusive. Given that executive functions have historically been considered a function controlled solely by the frontal lobes and that the cerebellum's role was considered to be limited to motor control, it is interesting that executive function deficits might be found following surgical resection of a posterior fossa tumor. It is hypothesized that disruption to the cerebellum results in damage to circuits involved in executive function, such as the cerebello-frontal circuit (Middleton & Strick, 2000; Heyder, Suchan, & Daum, 2004). While few studies have focused on executive functions in children surgically treated for posterior fossa tumors, the studies that exist have inconclusive results. Some studies have shown deficits in the executive function components of verbal and design fluency, inhibition, concept formation, problem solving, and mental flexibility, yet other studies show that these executive functions are not significantly impaired (Ater et al., 1996; Riva & Giorgi, 2000; Steinlin et al., 2003). Overall, no conclusive results have been found. These studies also have several limitations. First, they have very limited assessment of executive functions, and given that executive functions are multidimensional, two to three tasks are not sufficient in assessing executive functions. Also, the majority of these studies consisted of heterogeneous tumor types, which made it difficult to specify the deficit associated with the tumor.

A small number of studies have focused on executive functioning in children with homogenous tumor types. One such group consists of children treated for CPA, a type of tumor that is considered to have the best medical prognosis of any intracranial tumor in childhood (Cohen & Duffner, 1994; Hildebrand & Baleriaux, 2002). As a result of the treatment modality (surgical excision of tumor with no cranial radiation or chemotherapy) and good medical prognosis, children treated for CPA are thought to have minimal cognitive impairment. However, various studies have shown that these patients tend to display a variety of cognitive deficits. These children have consistently been shown to be at higher risk for impaired attention, visual-spatial ability, visual memory, academics, and adaptive functioning (Aarsen, Van Dongen, Paquier, Van Mourik, & Cateman-Berrevoets, 2004; Beebe et al., 2005). Inconclusive results have been found for intelligence (Beebe et al., 2005; Karatekin, Lazareff, & Asarnow, 2000; Riva & Giorgi, 2000). Consistent with studies on other posterior fossa tumors, no conclusions have been drawn regarding the impact of treatment on executive functions in children treated for CPA. Of the few studies that have been conducted, deficits have been found in concept formation, mental flexibility, and problem solving. Normal functioning inhibition and verbal fluency have also been noted (Aarsen et al., 2004; Karatekin et al., 2000). None of these studies has investigated the executive function components of planning and working memory. Interestingly, Karatekin and colleagues reported that parents in their study did not endorse executive function deficits in their children. They hypothesized that executive function deficits may be masked by the children's normal IQs, particularly their intact verbal skills. The few studies that exist on executive functioning in children with CPA have several limitations. These limitations include small sample sizes, limited assessment of executive functions, and uncertain generalizability resulting from the study being conducted in foreign countries. Thus, the level of executive function impairment in childhood survivors of CPA remains an unanswered question.

The current state of the literature is that there are no conclusive findings regarding whether executive function deficits are common among children surgically treated for CPA. Moreover, it has been hypothesized that normal intelligence might mask the executive function deficits and that parents are often unaware of these deficits. Given the ramifications of executive function deficits on a child's academic, psychological, and social functioning, it is necessary to more thoroughly explore the pattern of executive function deficits seen in child survivors of CPA. The current study attempted to address these issues and improve upon the previous studies by selecting a group of children with a homogeneous tumor types, specifically CPA.

PURPOSE OF STUDY AND HYPOTHESES

Purpose of Study

The purpose of the current study was to thoroughly examine executive functioning in pediatric patients treated for CPA. A secondary goal was to explore ratings of patients' executive functioning behaviors in the home and school environments. In addition, behavioral and emotional functioning in the home and school settings were examined. The final goal was to examine whether location of tumor in the cerebellum had an effect on executive and behavioral/emotional functioning. By examining the level of impairment in executive function, the proposed study hoped to provide information that could be utilized to develop interventions targeting cognitive and academic functioning.

Aims and Hypotheses

Specific Aim One

The first aim of the current study was to examine the effects of CPA on executive functioning in childhood survivors.

Hypothesis 1A: Participants will exhibit significantly worse performance on subtests measuring concept formation, mental flexibility, planning, fluency, and inhibition compared to the standardized test sample on the Delis-Kaplan Executive Function System (Delis, Kaplan, & Kramer, 2001). Please refer to Table 1 for specific subtests and variables used for this and the following hypotheses.

Hypothesis 1B: Participants will exhibit significantly worse performance on the components of concept formation and mental flexibility compared to the standardized test sample on the Wisconsin Card Sorting Test (Heaton, Chelune, Talley, Kay, & Curtis, 1993).

Hypothesis 1C: Participants will exhibit significantly worse performance on the Working Memory Index and associated subtests compared to the standardized test sample on the Wechsler Intelligence Scale for Children – Fourth Edition (Wechsler, 2003).

Rationale 1: Research on cerebellar diseases and surgically resected posterior fossa tumors have shown inconclusive results regarding deficits in the executive function components of concept formation, mental flexibility, planning, working memory, fluency, and inhibition (Ater et al., 1996; Exner, Weniger, & Irle, 2004; Gottwald, Wilde, Mihajlovic, & Mehdorn, 2004; Kalashnikova, Zueva, Pugacheva, & Korsakova, 2005; Levisohn, Cronin-Golomb, & Schmahmann, 2000; Malm et al., 1998; Riva & Giorgi, 2000; Steinlin et al., 2003). Limited research on pediatric CPA has shown inconsistent evidence regarding impairments in concept formation and mental flexibility (Aarsen, Van Dongen, Paquier, Van Mourik, & Cateman-Berrevoets, 2004; Karatekin, Lazareff, & Asarnow, 2000). In addition, the few CPA studies that have been conducted have not investigated multiple dimensions of executive functions and have consisted of small sample sizes. Despite the inconclusive results of executive function problems in various types of cerebellar pathology, however, the results as a whole imply that some degree of executive function problems may occur following insult to the cerebellum. Since the executive function components of concept formation, mental flexibility, planning, working memory, fluency, and inhibition have not been thoroughly investigated in patients surgically treated for CPA, the proposed study will utilize subtests from the Delis-Kaplan Executive Function System, Wisconsin Card Sorting Test, and subtests from the Working Memory Index from the Wechsler Intelligence Scale for Children – Fourth Edition to examine these areas. It is expected that the CPA group will exhibit significantly worse performance on the tests of executive function compared to the standardized test sample.

Specific Aim Two

The second aim of the current study was to explore patients' executive functioning behaviors in the home and school environments and to examine whether observable differences between executive functioning in these two environments exist.

Hypothesis 2A: Patient's executive functioning behaviors in the home environment will be rated significantly worse than the standardized group on the Behavior Rating Inventory of Executive Function (BRIEF) – Parent Form (Gioia, Isquith, Guy, & Kenworthy, 2000).

Hypothesis 2B: Patients' executive functioning behaviors in the school environment will be rated significantly worse compared to the standardization group on the BRIEF – Teacher Form (Gioia, Isquith, Guy, & Kenworthy, 2000).

Hypothesis 2C: Patients' executive functioning behaviors in the school environment will be rated significantly worse than the home environment.

Rationale 2: Although executive functions are sometimes found to be problematic in children surgically treated for cerebellar tumors, executive function behaviors in the home and school environment have not been thoroughly investigated. The hypothesis comparing the ratings between the school and home settings is purely exploratory based on the lack of previous research investigating this issue. However, it is hypothesized that teacher ratings will be significantly higher than parent ratings on the BRIEF because it is assumed that executive functions are utilized more frequently in the classroom due to the academically and cognitively challenging tasks. The proposed study will examine these topics as they may pertain to different intervention strategies being designed and implemented in one setting versus another.

Specific Aim Three

The third aim of the study was to explore patients' behavioral and emotional functioning in the home and school environments.

Hypothesis 3A: Patients will be rated as having significantly more problems with attention, hyperactivity, anxiety, and depression in the home environment compared to the standardization group on the Behavior Assessment System for Children - Second Edition (BASC-2) - Parent Rating Scale (Reynolds & Kamphaus, 2004).

Hypotheses 3B: Patients will be rated as having significantly more problems with attention, hyperactivity, anxiety, and depression in the school environment compared to the standardization group on the BASC-2 - Teacher Rating Scale (Reynolds & Kamphaus, 2004).

Hypothesis 3C: Ratings of patients' attention, hyperactivity, anxiety, and depression in the school environment will be significantly worse than in the home environment.

Rationale 3: Studies on cerebellar pathology and lesions have shown inconclusive results regarding problems with behavioral and emotional functioning, with some studies reporting problems with affective functioning and behavioral disturbances, while other studies show no impairments (Appollonio, Grafman, Schwartz, Massaquoi, & Hallet, 1993; Exner, Weniger, & Irle, 2004; Gottwald, Wilde, Mihajlovic, & Mehdorn, 2004; Neau, Arroyo-Anllo, Bonnaud, Ingrand & Gil, 2000; Schmahmann & Sherman, 1998). While mixed results on the presence of affective and behavioral problems have also been observed in posterior fossa tumor patients (Ater et al., 1996; Copeland, deMoor, Moore, & Ater, 1999; LeBaron, Zeltzer, Zeltzer, Scott, & Marlin, 1988; Levisohn, Cronin-Golomb, & Schmahmann, 2000; Maddrey et al., 2005; Riva & Giorgi, 2000; Steinlin et al., 2003), studies on pediatric CPA patients have been shown to exhibit difficulties with depressive behaviors, anxiety, attention problems, and behavioral disturbances (Aarsen, Van Dongen, Paquier, Van Mourik, & Catsman-Berrevoets, 2004; Beebe et al., 2005). The hypothesis comparing school and home ratings is purely exploratory based on the lack of previous research investigating this issue. However, it is hypothesized that the increased demands on a child's cognitive and emotional abilities in the classroom and with peers would result in greater difficulties.

Specific Aim Four

The final aim of the study was to examine whether location of tumor or lesion has an effect on executive functions in childhood survivors of CPA. The tests and variables used for the following hypotheses are found in Table 1.

Hypothesis 4A: Patients with pilocytic astrocytomas in the right cerebellar hemisphere will perform significantly worse on tasks involving language-based executive functions.

Rationale 4A: Research on cerebellar circuitry demonstrates that some areas within the cerebellar hemispheres are connected with the contralateral cerebral hemisphere, e.g., the right cerebellar hemisphere is interconnected with the left cerebral hemisphere (Brodal & Bjaalie, 1997; Dum & Strick, 2003; Heyder, Suchan, & Daum, 2004; Middleton & Strick, 1994, 2000, 2001; Schmahmann, 1991, 2001; Snell, 1997, Voogd, 2003). Given that language functions are often lateralized to the left cerebral hemisphere, it might be expected that compromise to the right cerebellar hemisphere would negatively impact functionality of interconnections to the left cerebral hemisphere, thereby interfering with the efficiency of language as it relates to executive functions. Additionally, research on patients with right-sided cerebellar lesions and pathology has shown impairment in language functions; however, other studies have not found evidence to support these findings (Gottwald, Wilde, Mihajlovic, & Mehdorn, 2004; Hokkanen, Kauranen, Roine, Salonen, & Kotila, 2006; Kalashnikova, Zueva, Pugacheva, & Korsakova, 2005; Levisohn, Cronin-Golomb, & Schmahmann, 2000; Molinari, Petrosini, Misciagna, & Leggio, 2004; Riva & Giorgi, 2000; Steinlin et al., 2003). Therefore, the proposed study will examine this area in children with CPA.

Hypothesis 4B: Patients with pilocytic astrocytomas in the left cerebellar hemisphere will perform significantly worse on tasks involving visual-spatial based executive functions.

Rationale 4B: As noted above, research on cerebellar circuitry demonstrates that some areas within the cerebellar hemispheres are connected with the contralateral cerebral hemisphere, e.g., the left cerebellar hemisphere is interconnected with the right cerebral hemisphere. Since visual-spatial functions are often lateralized to the right cerebral hemisphere, it would be expected that these functions would be lateralized to the left cerebellar hemisphere. Although some research on patients with left-sided cerebellar lesions and pathology have shown impairment in visual-spatial functions, aggregate evidence is inconclusive (Gottwald, Wilde, Mihajlovic, & Mehdorn, 2004; Hokkanen, Kauranen, Roine, Salonen, & Kotila, 2006; Kalashnikova, Zueva, Pugacheva, & Korsakova, 2005; Levisohn, Cronin-Golomb, & Schmahmann, 2000; Molinari, Petrosini, Misciagna, & Leggio, 2004; Riva & Giorgi, 2000; Steinlin et al., 2003). Therefore, the proposed study will examine this area in children with CPA.

Hypothesis 4C: Patients with lesions in the vermis will be rated as having significantly more behavioral and emotional problems.

Rationale 4C: Research on patients with lesions or pilocytic astrocytomas in the vermis has suggested that some of these patients exhibit behavioral and emotional problems; however, inconsistent evidence has been found regarding the role of the vermis in behavioral and emotional functioning (Levisohn, Cronin-Golomb, & Schmahmann, 2000; Riva & Giorgi, 2000; Salman, 2002; Schmahmann & Sherman, 1998; Steinlin et al., 2003). Thus, the proposed study will examine this area.

Hypothesis 4D: Patients with lesions in the posterior lobes will perform significantly worse on the tasks than patients with lesions in other areas of the cerebellum.

Rationale 4D: Research in this area is emerging; however, studies on the circuitry of the cerebellar posterior lobes in humans and primates have shown that they are interconnected with areas in the parietal, temporal, and occipital lobes of the cerebral cortex, as well as the medial, lateral, and dorsal areas of the prefrontal cortex (Brodal & Bjaalie, 1997; Dum & Strick, 2003; Heyder, Suchan, & Daum, 2004; Middleton & Strick, 1994, 2000, 2001; Schmahmann, 1991, 2001; Snell, 1997, Voogd, 2003). Research has also suggested that lesions in the posterior lobes can sometimes result in impairments in executive and cognitive functioning (Exner, Weniger, & Irle, 2004; Kalashnikova, Zueva, Pugacheva,

& Korsakova, 2005; Schmahmann, 1998). The proposed study will further investigate this area by examining performance on tests of executive function in a subgroup of CPA patients with tumors in the posterior cerebellum.

CHAPTER THREE
Methodology

Subjects

The study consisted of 20 children between the ages of 8 years, 0 months and 16 years, 11 months who were treated for CPA. Participants were recruited from the departments of Neurosurgery and Neuro-oncology at Children's Medical Center in Dallas. Subjects were selected according to the following inclusion and exclusion criteria:

<u>Inclusion Criteria for CPA Patients</u>

1. Radiographically diagnosed cerebellar region brain tumor
2. Histopathologically diagnosed pilocytic astrocytoma
3. Surgical treatment only
4. No history of tumor recurrence
5. Current age: eight to 16 years
6. At least one-year post surgery
7. Proficiency in English
8. Completion of the signed informed consent by a parent or legal guardian
9. Subject's assent to participate in the protocol

<u>Exclusion Criteria for CPA Patients</u>

1. Treatment with radiation and/or chemotherapy
2. Inability to speak and read in English

3. Any significant neurological, developmental, or psychiatric disorder or disability that would prevent the completion of the neuropsychological test battery

The mean age for the total sample was 12.84 years (SD = 2.67). The mean estimated intellectual ability (FSIQ-2) for the total sample was a standard score of 103 (SD = 15.29, Median = 101), with a range from 77 to 129. The sample consisted of 55% boys (n = 11) and 45% girls (n = 9). Forty-five percept (n = 9) of the sample was Hispanic, 40% (n = 8) Caucasian, 10 % (n = 2) African-American, and 5% (n = 1) Asian.

Materials

Medical information was obtained retrospectively via chart review. Data collected consisted of medical information required for standard of care treatment for pediatric brain tumor patients, including gender, date of birth, preoperative conditions, etiology of the tumor, radiographic data, date of surgery, surgical procedure, follow-up outcome, other treatment modalities, and medical complications (i.e., hydrocephalus, shunt insertion, infections). The medical chart review form can be found in Appendix A. Location of tumor was obtained through examination of previous neuroimaging scans (magnetic resonance imaging, MRI, or computed tomography, CT) and review of neuroradiology reports by a clinical neuropsychologist with extensive knowledge of the cerebellum.

Parents or guardians completed a four-page questionnaire inquiring about the patient's developmental, school, and medical history, family educational history, and current parental employment information. The data was collected for a more detailed understanding of the sample's psychological, educational, and demographic characteristics. The patient history questionnaire can be found in Appendix B. Prospective data collection was obtained through a multidimensional assessment of executive functions administered to all participants. The test battery assessed the executive function components of cognitive flexibility, fluency, inhibition, problem solving, concept formation, planning, and working memory. The battery consisted of the following measures.

Wechsler Abbreviated Scale of Intelligence

The Wechsler Abbreviated Scale of Intelligence (WASI; The Psychological Corporation, 1999), a brief measure of intelligence, was meant to serve as a covariate if warranted. Executive functions are closely associated with intellectual ability and performance on IQ measures, and have been shown to covary with performance on executive function measures (Obonsawin, Crawford, Page, Chalmers, Cochrane, & Low, 2002; Wood & Liossi, 2007). If a significant difference in intellectual ability is found between the CPA group and the normative test mean, then the Full Scale IQ (FSIQ) - 2 will be used as a covariate, so that the effect of intellectual ability will be removed from executive function test performance. As a result, observed differences in executive functions will not be related to intellectual ability.

The WASI (The Psychological Corporation, 1999) was standardized on a nationally representative sample of 2245 children and adults age 6 to 89 years. Stratification was based on gender, ethnicity, educational level, and geographical location. The Vocabulary and

Matrix Reasoning subtests, which comprise the FSIQ-2, were used. Internal consistency was obtained using the split-half method and corrected by the Spearman-Brown formula. In a child sample, the internal consistency reliability coefficients for the IQ scales were r = .96 for the Verbal IQ, r = .96 for the Performance IQ, and r = .98 for the Full Scale IQ. The WASI Full Scale IQ - 2 (FSIQ-2) has a high correlation of .86 with the FSIQ on the Wechsler Intelligence Scale for Children- Fourth Edition (WISC-IV; Wechsler, 2003). Given its quick administration time (approximately 15 to 30 minutes) and its high correlation with the WISC-IV FSIQ, the WASI FSIQ-2 was used in order to be time effective.

Delis-Kaplan Executive Function System

Selected subtests were used from the Delis-Kaplan Executive Function System (D-KEFS; Delis, Kaplan, & Kramer, 2001), a comprehensive battery of nine stand-alone tests that measure components of executive functions. The D-KEFS is comprised of either relatively new tests or modifications of commonly used tests of executive functions. Subtests used in the current study included the Trail Making Test, Verbal Fluency Test, Design Fluency Test, Color-Word Interference, Twenty Questions Test, and Tower Test. These subtests were chosen given that they assess the executive function components of concept formation, mental flexibility, planning, fluency, and inhibition. In addition, the D-KEFS was used instead of multiple measures of executive function (e.g., Trail Making Test- Parts A and B, FAS test, Stroop Color-Word Test, Tower of London) because all the subtests are normed on the same national standardization sample (Delis et al., 2001). The D-KEFS was standardized on a nationally representative sample of people 8 to 89 years of age. The sample of 1750 people was stratified according to age, gender, ethnicity, education level, and geographic region. Internal consistency was obtained using the split-half method and corrected by the Spearman-Brown formula. Internal consistency reliability coefficients range from moderate to high for the Trail Making Test (r = .57-.81), low to high for Verbal Fluency Test (r = .37-.90), moderate to high for Color-Word Interference Test (r = .62-.86), low to high for Twenty Questions Test (r = .10-.87), and moderate to high for the Tower Test (r = .43-.84). Internal consistency reliability coefficients were not reported for Design Fluency Test, since these procedures were reportedly unable to be conducted due to the test's item interdependence. Validity studies on clinical samples with the D-KEFS have demonstrated moderate sensitivity in assessing executive function deficits in various clinical groups, including focal lesions, dementia, multiple sclerosis, schizophrenia, and attention disorders (Delis, Kramer, Kaplan, & Holdnack, 2004). Total administration time for the selected subtests is approximately one hour.

Wisconsin Card Sorting Test

Participants were administered the Wisconsin Card Sorting Test (WCST; Heaton, Chelune, Talley, Kay, & Curtis, 1993), a test that assesses the executive function components of problem solving and cognitive flexibility. Individuals are required to sort up to 128 cards according to a sorting principle by using the examiner's feedback. The WCST has been standardized on a total of 899 normal children and adults ranging from six to 89 years of age. Generalizability coefficients, which measure the accuracy of the instrument in measuring a person's true scores, ranged from .39 to .72 in a sample of children and adolescents. Validity studies with the WCST indicate that it has reasonable sensitivity in differentiating different types of clinical groups (frontal lobe dysfunction, focal brain lesions, schizophrenia, and other neurologically impaired populations) from normal groups (Heaton et al., 1993). The WCST was used instead of the D-KEFS Sorting Test since it is frequently used as a measure of executive function in research and clinical settings. Administration time is approximately 20 to 30 minutes.

Digit Span and Letter-Number Sequencing

In addition, participants were administered the core subtests that comprise the Working Memory Index on Wechsler Intelligence Scale for Children- Fourth Edition (WISC-IV; Wechsler, 2003), which consist of Digit Span and Letter-Number Sequencing. Digit Span requires the child to repeat numbers in the same or reverse order. Digit Span Forward and Digit Span Backward are composed of 16 trials each. Letter-Number Sequencing, which is composed of 30 trials, requires the child to repeat numbers and letters in a specific order. The WISC-IV was standardized on a nationally representative sample of 2200 children aged 6 years to 16 years 11 months. The sample was stratified according to age, gender, ethnicity, parental education, and geographic location. Internal consistency was obtained using the split-half method and corrected by the Spearman-Brown formula. Internal consistency reliability coefficients were in the high range for Digit Span (r = .81-.92), Letter-Number Sequencing (r = .85-.92), and the Working Memory Index (r = .90-.93). Validity studies on the standardization sample using exploratory factor analyses demonstrated that Digit Span and Letter-Number Sequencing subtests had primary loadings on the Working Memory factor (.62 for both subtests). Digit Span and Letter-Number Sequencing were used because they are an efficient and reliable method of assessing working memory. Total administration time for these subtests is approximately 10 minutes.

Behavior Rating Inventory of Executive Function

For each participant, one parent and two teachers (English and Mathematics; or one teacher if the child had the same teacher for all subjects) were asked to complete the Behavior Rating Inventory of Executive Function (BRIEF; Gioia, Isquith, Guy, & Kenworthy, 2000), a questionnaire that evaluates overt executive function behaviors in school age children. The BRIEF Parent and Teacher Forms were standardized using 1419 parents and 720 teachers of children aged 5 to 18 years, respectively. The normative sample was obtained through public and private school in Maryland and approximated the sex, socioeconomic status, ethnic composition, age, and geographical population density of the United States. Internal consistency reliability coefficients (Cronbach's alpha) were high for both the Parent Forms ($r = .82$-$.98$) and Teacher Forms ($r = .80$-$.98$). Validity studies using clinical samples have demonstrated moderate to strong correlations between the BRIEF and other questionnaires, including the Child Behavior Checklist, ADHD Rating Scale- IV, Behavior Assessment System for Children, Conner's Rating Scale. The BRIEF was used instead of other behavioral questionnaires because it specifically assesses executive function behaviors in children. The BRIEF allows for comparison between children's executive functioning behaviors in the home and school environments. The questionnaire takes approximately 10 to 15 minutes to complete.

Behavior Assessment System for Children - Second Edition

For each participant, one parent and two teachers (English and Mathematics; or one teacher if the child had the same teacher for all subjects) were asked to complete the Behavior Assessment System for Children - Second Edition (BASC-2, Reynolds & Kamphaus, 2004), a questionnaire designed to identify emotional and behavioral problems in children. The BASC-2 was standardized on both general-population samples and clinical samples across forms (Teacher Rating Scale, Parent Rating Scale, Self-Report of Personality). Only the teacher and parent versions were used in the current study. The BASC-2 was standardized using a total of approximately 13,000 parents, teachers, and children aged 2 to 18 years of age. Internal consistency reliability coefficients (Cronbach's alpha) were high for both the parents and teachers, ranging from r = .65 to .95 for the Parent Rating Scales and r = .74 to .97 for the Teacher Rating Scales. Some validity studies are used to show correlations with other behavioral questionnaires by having the same parents (or teachers) complete a BASC-2 and another behavioral questionnaire. Validity studies with the BASC-2 Teacher Rating Scale have demonstrated mostly moderate to strong correlations with the Achenbach System of Empirically Based Assessment, Conner's Teacher Rating Scale - Revised, and the original BASC Teacher Rating Scale. Validity studies with the BASC-2 Parent Rating Scale have demonstrated mostly moderate to strong correlations with the Achenbach System of Empirically Based Assessment, Conner's Parent Rating Scale - Revised, Behavior Rating Inventory of Executive Function, and the original BASC Parent Rating Scales. The BASC-2 was used as a screening measure to identify any possible emotional or behavioral problems that may affect executive functions. The questionnaire takes approximately 20 minutes to complete.

Procedures

Participant Recruitment

Approval to conduct the study was obtained from the Institutional Review Board (IRB) of the University of Texas Southwestern Medical Center at Dallas and Children's Medical Center of Dallas (CMCD). The names of children who met the eligibility criteria were obtained from the Neurosurgery/Neuro-Oncology patient database at CMCD. Parents of the identified children were contacted by phone, mail, and/or during their child's regularly scheduled neuro-oncology clinic visit. A description of the study was provided and they were asked to participate. If they agreed, the parent(s) and child were scheduled for an appointment. Written, informed consent was obtained for each participant during his or her clinic visit or scheduled appointment.

All participants and parents gave consent prior to neuropsychological testing. The examiner provided the parent(s) and child with a full description of the study, including the purpose, benefit, and risks, by discussing in detail the elements of the IRB-approved informed consent document. The consent form is included in Appendix C. Parents and children were encouraged to ask questions regarding their participation in the study. They were made aware that participation was voluntary and that they could withdraw at any time. After all questions were answered, the examiner obtained written informed consent from the parent(s).

The examiner then verified that the child understood his/her role in the study and that participation was voluntary; verbal and written assent were subsequently obtained by the examiner. The parent(s) then completed the Health Insurance Portability and Accountability Act (HIPAA) Release document, which authorized the use of their health information for the purpose of the study. Signed copies of the Informed Consent and HIPAA Release forms were provided to the parent(s), CMCD Medical Records, and the departments of Neurosurgery/Neuro-Oncology. Children were enrolled in the study upon completion of the informed consent process.

A request for protocol modification was submitted to and approved by the Institutional Review Board toward the latter part of the recruitment phase with the hope of improving recruitment. The original age range in the study was between 8 and 16 years of age, and the modification extended the age range to 17-18 year olds. However, none of the eligible subjects in the extended age range agreed to participate.

Data Collection

Each child presented for the appointment with one or both parents. The parents completed the history questionnaire, BRIEF - Parent Form, and BASC-2 - Parent Rating Scale. These forms took approximately 1.5 hours to complete. During the introduction, the parents were asked if they would be willing to have their child's English and Math teachers, or their primary classroom teacher if applicable, complete a teacher's version of the BRIEF and BASC-2. All parents agreed. The parents either contacted and delivered the questionnaires to the teachers or the investigator contacted the teacher and mailed the questionnaires. Follow-up calls were made and letters/emails were sent to teachers in order to increase the number of questionnaires completed.

While the parents completed the questionnaires, the child was being tested in another room by an examiner who was trained in individual tested and in the administration of the selected tests. In order to maximize standardization and increase internal validity, all children were evaluated by the same examiner and with the same age-appropriate neuropsychological battery administered in the following order: WASI (Vocabulary, Matrix Reasoning), D-KEFS (Trail Making Test, Verbal Fluency Test, Design Fluency Test, Color-Word Interference Test, Twenty Questions Test, Tower Test), WCST, and Digit Span and Letter-Number Sequencing from the WISC-IV.

Statistical Analyses

The hypotheses were explored with the one-sample t-test, binomial test, and Wilcoxon Signed Rank test. The assumptions underlying the one-sample t-test were that the observations were independent and the sample values were normally distributed in the population (Gravetter & Wallnau, 1992). The assumption of independence was met because the scores were obtained from independent individuals. In order to check the assumption of normality, the Shapiro-Wilk test was conducted. When the data were significantly non-normal, a nonparametric test, the binomial test, was utilized. The assumptions underlying the binomial test are that the observations are independent of each other (Green & Salkind, 2003).

The Wilcoxon Signed Rank test was used in hypotheses that compared parent and teacher ratings for the same child. The assumptions underlying the Wilcoxon Signed Rank test are that the paired values are independent of all other pairs and that the distribution of scores is continuous (Green & Salkind, 2003). The assumptions were met because there was only one parent-teacher pair per child, and the scores for parents and teachers were on an interval scale. Data were analyzed using the Statistical Package for the Social Sciences for Windows: Grad Pack, Version 15.0 (SPSS, 2006). All tests, except when specified, were one-sided and probability for significance was set at $p < .05$.

CHAPTER FOUR
Results

DEMOGRAPHIC CHARACTERISTICS

Medical information for the group is provided in Table 2. The sample had a mean age at diagnosis/surgery of 5.40 years (SD = 1.90, Median = 5.13, Range = 2.58-11.00), with a mean of 7.40 years (SD = 3.07, Median = 7.29, Range = 1.17-14.08) from date of diagnosis to evaluation. Seventy percent (n = 14) of the participants had hydrocephalus; of the participants with hydrocephalus, 29% (n = 4) had a history of only shunt insertion, 36% (n = 5) only ventriculostomy, and 21% (n = 3) had both a shunt and a ventriculostomy. Eighty percent (n = 16) of the sample had a gross total resection and 20% (n = 4) had a subtotal resection of the tumor.

The following information was obtained from the history form completed by the participants' parents at the time of evaluation (Table 3). Thirty percent (n = 6) of the participants were rated as having below average motor development and 35% (n = 7) had undergone occupational or physical therapy. Twenty percent (n = 4) were reported as having below average speech/language development and 30% (n = 6) had previously obtained speech/language therapy. Twenty percent (n = 4) of participants had a history of learning problems and 30% (n = 6) currently had below average academic performance as rated by their parents. In terms of school support, 15% (n = 3) attended an Early Childhood Intervention (ECI) program or a Preschool Program for Children with Disabilities (PPCD) and 45% (n=9) of participants had received special education services. Half of the participants (n = 10) were described as having a history of behavioral/emotional problems.

The FSIQ-2 was planned to be used as a covariate if a significant difference was found between the CPA group and the normative test mean. The sample mean of 103 (SD = 15.29) was not significantly different from the normative mean of 100, t (19) = .88, p = 39; therefore, FSIQ-2 was not used in the analyses.

RESEARCH HYPOTHESES

Power Analysis and Sample Size software (PASS) was used to determine that a sample size of 27 participants would provide 81% power to detect a difference of one-half standard deviation with p = .05. for the planned statistical analyses. Ultimately, only 20 participants were recruited for the current study. Power analyses indicated that a sample of 20 participants would provide 80% power to detect an effect size of *d* = .58 at p = .05 using a one-sided one-sample t-test, assuming normality. For a one-sided binomial test, power analyses indicated that a sample of 20 participants would provide 80% power to detect an effect size of *g* = .30 at p = .05.

It is important to note that ratings from math and English teachers were requested for each participant; however, several teachers did not complete the questionnaires. In total, 18 teacher questionnaires were received. Four children received questionnaires from both their math and English teachers, whereas 10 children received only one questionnaire. From the children with two questionnaires, one teacher questionnaire was randomly selected. Thus, 14 teacher questionnaires were used in the analyses (4 math teachers, 7 English teachers, and 3 grade teachers).

Study Aim One

The first study aim was to examine the effects of CPA on executive functioning in childhood survivors. To address this aim, the participants were administered a battery of neuropsychological tests that assessed executive function. The battery consisted of the Delis-Kaplan Executive Function System, Wisconsin Card Sorting Test, and the Working Memory Index and associated subtests from the Wechsler Intelligence Scale for Children - Fourth Edition.

Hypothesis 1A

This hypothesis stated that the CPA group would exhibit significantly worse performance on subtests measuring concept formation, fluency, inhibition, mental flexibility, and planning compared to the standardized test sample on the Delis-Kaplan Executive Function System (D-KEFS).

The majority of the variables for this hypothesis were approximately normal. However, the distributions from the variables Verbal Fluency Test: Category Switching ($p = .04$) and Twenty Questions Test: Total Weighted Achievement ($p = <.01$) were significantly non-normal and the variables Design Fluency Test: Empty Dots ($p = .13$) and Twenty Questions Test: Initial Abstraction ($p = .06$) showed a trend for being non-normal.

The binomial test was conducted on the variables Verbal Fluency Test: Category Switching, Twenty Questions Test: Total Weighted Achievement, Design Fluency Test:

Empty Dots, and Twenty Questions Test: Initial Abstraction to determine if there were significant differences in the proportion of participants who fell above the normative mean of 10. None of these tests were found to be significant; however, a trend toward significance was found for Twenty Questions: Initial Abstraction ($p = .06$). Test scores for these variables were generally below the normative mean of 10, except for Twenty Questions Test: Total Weighted Achievement, which had a higher proportion of subjects that scored above the normative mean of 10. Effect sizes ranged from small to medium (*g* = -.05-.20). The results of the binomial test can be found in Table 4.

The results of the one-sample t-tests for the other measures conducted on Hypothesis 1A are reported in Table 5. None of the tests were found to be significant; however, a trend toward significance was found for Verbal Fluency Test: Letter Fluency ($p = .07$) and Design Fluency Test: Filled Dots ($p = .06$). Effect sizes, *d*, for the tests ranged from -.36 to .05, which indicate a small effect. Means for the measures were generally lower than 10, with the variable Verbal Fluency Test: Letter Fluency having the lowest mean at 8.90. The variable Tower Test- Achievement had the highest mean with 10.10.

Overall, the hypothesis was not supported. The children's performance in this sample was not significantly different from the normative means on any of the selected subtests from the D-KEFS. The results suggest that concept formation, fluency, inhibition, mental flexibility, and planning in childhood survivors of CPA are not significantly different from other children their age.

Hypothesis 1B

It was predicted that the CPA group would exhibit significantly worse performance on the components of concept formation and mental flexibility compared to the standardized test sample on the WCST. No significant differences were found using the Shapiro-Wilk test of normality. One-sample t-tests were conducted to evaluate whether the CPA group means were significantly different from the respective normative means, which were 50 and 50.

The results for Hypothesis 1B are reported in Table 6. None of the tests were found to be significant. Effect sizes, *d*, for Conceptual Level Responses and Perseverative Responses were .30 and .41, respectively, which indicate a small effect. The means of 53.15 for Conceptual Level Responses and 54.40 for Perseverative Responses were higher than the normative mean of 50, which contradicted what the hypothesis predicted.

Overall, the group's performance was not significantly different from the normative means on the WCST. Thus, the hypothesis was not supported. The results suggest that childhood survivors of CPA do not exhibit significant problems with concept formation and mental flexibility.

Hypothesis 1C

This hypothesis stated that the CPA group would exhibit significantly worse performance on working memory compared to the standardized test sample on the WISC-IV. One-sample t-tests were conducted to evaluate whether the CPA group means were significantly different from the test means. The binomial test was also utilized with variables that did not meet the assumptions for the one-sample t-test.

The assumptions of independence and normality underlying the one-sample t-test were met with the variables in this hypothesis except with the variable Letter-Number Sequencing, which showed a trend ($p = .07$) on the Shapiro-Wilk test of normality. In order to be conservative with the analyses and to explore whether the near violation of the assumption of normality had a significant influence on the Letter-Number Sequencing variable, the binomial test was conducted. The observed proportion of scores that fell above the mean of 10 compared to below was not significant. The results of the binomial test can be found in Table 7.

The results of the one-sample t-tests for Hypothesis 1C are reported in Table 8. None of the tests were significant. Effect size, *d*, for the tests ranged from .00 to .03, which indicates a very small effect. In general, there was no difference between the normative test means and the CPA group's means on the Working Memory Index ($M = 100$), Digit Span ($M = 10.10$), and Letter-Number Sequencing ($M = 10.10$).

Overall, the sample's performance was not significantly different from the normative means on any of the subtests above. Thus, the hypothesis was not supported. The results indicate that working memory in childhood survivors of CPA is not significantly different than other children their age.

Study Aim Two

The second study aim was to explore the CPA group's executive functioning behaviors in the home and school environments. To address this aim, the participants' parents and teachers each completed the BRIEF, a questionnaire that evaluates overt executive functions in school age children.

Hypothesis 2A

It was predicted that the CPA group's executive functioning behaviors in the home environment would be rated as significantly more problematic than the standardized test sample on the BRIEF– Parent Form. One-sample t-tests were conducted when the data were normally distributed and the binomial test was utilized when the data were significantly non-normal. Each participant had one parent questionnaire; therefore, 20 parent ratings were included in the analyses for this hypothesis.

The variables for this hypothesis were not significantly different from a normal distribution on the Shapiro-Wilk test, except the variables BRIEF Parent- Shift ($p = .07$) and BRIEF Parent- Emotional Control ($p = .06$), which showed a trend. The binomial test was conducted on the variables BRIEF Parent- Shift and BRIEF Parent- Emotional Control to determine if there were significant differences in the proportion of participants who fell above and below the normative mean of 50 (Table 9). The test was significant for BRIEF Parent- Shift ($p = .02$), with 75% of scores falling above a mean of 50. Scores above the mean indicate more problematic behaviors.

The results for the one-sample t-tests for the other measures conducted on Hypothesis 2A are reported in Table 10 All variables except one (BRIEF Parent- Organization of Materials, $p = .09$) were found to be significant; these variables were all higher than the normative mean, which indicate a higher incidence of problems with executive functioning behaviors in the everyday environment. Effect sizes, *d*, for the tests ranged from a small effect of .32 for the Organization of Materials scale to a large effect of 1.31 for the Initiate scale.

In most cases, the hypothesis was supported. Parents rated the CPA group's executive functioning behaviors as being significantly worse than their peers. In the area of organization of materials, no difference was found between the CPA group and the standardized test sample.

Hypothesis 2B

This hypothesis stated that the CPA group's executive functioning behaviors in the school environment would be rated as significantly more problematic compared to the standardization group on the BRIEF - Teacher Form. Depending upon whether the data were normally distributed, the one-sample t-test or the binomial test was utilized.

Only one of the variables for this hypothesis, Working Memory, was not significantly different from a normal distribution. The variables Initiate ($p = .06$), Monitor ($p = .15$), and Metacognition Index ($p = .06$) were trended toward non-normal distributions. The distributions for the remaining variables were significant on the Shapiro-Wilk test.

Except for Working Memory, the binomial test was conducted on the variables from the BRIEF- Teacher Form to determine if significant differences were present in the proportion of participants who fell above and below the normative mean of 50. Mean test scores for these variables were generally above the normative mean of 50, which indicate a greater presence of problems. However, none of these tests were significant. The results of the binomial test can be found in Table 11.

The one-sample t-test conducted with the variable Working Memory was found to be significant (Table 12). The effect size, *d*, of .71 indicates a medium to high effect. The results support the conclusion that children who have been treated for CPA have somewhat more problems with working memory in the classroom than average. Overall, however, no other significant differences were found in these participants' executive function behaviors in the classroom.

Hypothesis 2C

It was predicted that participant's executive functioning behaviors in the school environment would be rated as significantly more problematic than in the home environment. The Wilcoxon Signed Ranks test was used to examine whether ratings from the BRIEF-Teacher Form were worse than from the Parent Form. Fourteen parent-teacher pairs were used in the analyses. Overall, the hypothesis was not supported (Table 13)

In summary, parent ratings suggested many problems with the CPA group's executive functioning behaviors in the home compared to the general population, while teacher ratings showed that the CPA group had more problems than peers with working memory in the school setting. No significant differences were observed when comparing parent and teacher ratings.

Study Aim Three

The third study aim was to explore the CPA group's behavioral and emotional functioning in the home and school environments. To address this aim, the participants' parents and teachers each completed the BASC-2, a questionnaire designed to identify emotional and behavioral problems in children.

Hypothesis 3A

This hypothesis stated that participants would be rated as having significantly more problems with attention, hyperactivity, anxiety, and depression in the home environment compared to the standardized test sample on the BASC-2 Parent Rating Scale. When data were normally distributed, one-sample t-tests were conducted on the parent scores to evaluate whether their means were significantly different from the respective normative means. When the data were significantly non-normal, the binomial test was utilized to determine if there were significant differences in the proportion of participants who fell above and below the normative mean of 50.

The distribution for the variable Anxiety ($p = .02$) was found to be significantly different from a normal distribution. The binomial test was conducted on the variable Anxiety and was not found to be significant ($p = .50$). Effect size was small ($g = .00$). The results of the binomial tests are found in Table 14.

The results of the one-sample t-tests for the other variables in Hypothesis 3A are reported in Table 15. Of the variables of interest (Attention, Hyperactivity, and Depression), only Depression ($p < .01$) was found to be significant. The effect size, *d*, ranged from a low effect of .24 for the Hyperactivity scale to a medium effect of .71 for the Depression scale. Overall, the hypothesis was partially supported. Parents rated the CPA group as demonstrating significantly more problems with depressive behaviors in the home setting than other children their age. However, the CPA group's activity level, attention, and anxiety were similar to their peers.

Hypothesis 3B

It was predicted that participants would be rated as having significantly more problems with attention, hyperactivity, anxiety, and depression in the school environment compared to the standardized group on the BASC-2 - Teacher Rating Scale. One-sample t-tests were conducted if data were normally distributed and binomial tests were conducted if the data were significantly non-normal.

The distributions for Hyperactivity ($p < .01$), Anxiety ($p = .03$), and Depression ($p = .04$) were found to be significantly different from a normal distribution. Binomial tests were conducted on the Hyperactivity, Anxiety, and Depression scales, and were not found to be significant. Mean test scores for these variables were below the normative mean of 50. Effect sizes, *g*, were generally small. The results of the binomial tests are found in Table 16.

The one-sample t-test conducted with the variable Attention Problems was not found to be significant. The results of the one-sample t-test are reported in Table 17.The effect size, *d*, of .14 indicates a small effect. Overall, the hypothesis was not supported. It appears that children treated for CPA do not exhibit more problems with hyperactivity, anxiety, depression, and attention in the school environment than other children their age.

Hypothesis 3C

This hypothesis stated that ratings of participant's attention, hyperactivity, anxiety, and depression in the school environment would be rated as significantly more problematic than in the home environment. The Wilcoxon Signed Ranks test was used to examine whether ratings on the selected variables from the BASC-2 Teacher Rating Scale were worse than from the Parent Rating Scale. Fourteen parent-teacher pairs were used in the analyses. None of these tests were found to be significant (Table 18). Overall, the hypothesis was not supported.

Study Aim Four

The final study aim was to examine whether the location of the tumor in the cerebellum had an effect on the results of executive function tests in the CPA group. This set of hypotheses was described as "aspirational in nature" from the inception of the study because of the large sample size required to conduct appropriate statistical analyses. Ultimately, the sample size obtained was not sufficient to perform the desired analyses between the groups. Descriptive statistics are provided instead to illustrate the group's performance. It is important to note that most participants had tumors that invaded multiple areas of the cerebellum. However, participants were divided into dichotomous groups for each comparison (e.g., participants with tumor in the right cerebellar hemisphere versus participants without tumor in the right cerebellar hemisphere).

Hypothesis 4A

It was predicted that participants with CPA in the right cerebellar hemisphere would perform significantly worse on tasks involving language-based executive functions. Six children had tumors that invaded the right cerebellar hemisphere, while 14 children had no right cerebellar involvement. Children with tumors that invaded the right cerebellar hemisphere had mean scores ranging from average to high average on the language-based executive function tests (see Table 1 for list of subtests used). The Verbal Fluency Test: Category Switching had the lowest mean (M = 9.00, SD = 4.10), while Letter-Number Sequencing had the highest score with a mean of 12 (SD = 2.61). Mean scores for children who did not have right cerebellar hemisphere tumor involvement were all in the average range. Means ranged from a low of 8.50 (SD = 3.03) on the Verbal Fluency Test: Letter Fluency to a high of 10.21 (2.89) on Digit Span. Means, standard deviations, medians, and ranges for these variables are reported in Table 19.

Hypothesis 4B

This hypothesis stated that participants with CPA in the left cerebellar hemisphere would perform significantly worse on tasks involving visual-spatial-based executive functions. Twelve children had tumors that invaded the left cerebellar hemisphere and eight children had no left cerebellar involvement. Children with tumors that invaded the left hemisphere had mean scores on the visual-spatial-based executive function tests that all fell in the average range. A list of the test used in this hypothesis can be found in Table 1. The data below are presented as scaled scores (*M* = 10, SD = 3) or T scores (*M* = 50, SD = 10). The Trail Making Test: Letter-Number Switching had the lowest mean (M = 9.08, SD = 3.40), while the WCST: Perseverative Responses had the highest mean with a score of 55.83 (SD = 10.79). Mean scores for children who did not have left cerebellar hemisphere tumor involvement ranged from low average to average. Means ranged from a low of 7.88 (SD = 4.94) on Design Fluency Test: Switching to a high of 52.25 (SD = 11.20) on WCST: Perseverative Responses. See Table 20 for means, standard deviations, medians, and ranges for these variables. Although the descriptive analyses are not sufficient for drawing conclusions, it is interesting that the group with no left cerebellar hemisphere involvement had the lowest mean score and appeared to have lower scores in general, which is contrary to the hypothesis.

Hypothesis 4C

It was predicted that participants with CPA in the vermis would be rated as having significantly more behavioral and emotional problems. Twelve children had tumors that invaded the vermis, while eight children had no vermis involvement. Children with tumors in the vermis had mean scores on the BASC-2 Parent Rating Scale that ranged from a low of 52.33 (SD = 10.75) on Attention Problems to a high of 58.83 (SD = 10.40) on Depression. On the Teacher Rating Scale, these children had a low of 49.25 (SD = 10.20) on Learning Problems to a high of 56.38 (SD = 10.68) on Somatization. For the children who did not have tumor involvement in the vermis, Conduct Problems (M = 49.63, SD = 9.90) had the lowest mean on the Parent Rating Scale, while Withdrawal had the highest mean (M = 62.13, SD = 9.98). The mean score for the Withdrawal scale fell in the at-risk range, which suggests that these behaviors have the potential of developing into severe problems. On the Teacher Rating Scale, Anxiety had the lowest mean (M = 44.83, SD = 6.05) and Attention Problems had the highest mean (M = 49.83, SD = 10.30). Means, standard deviations, medians, and ranges for these variables are reported in Table 21. The means from the parent and teacher BASC-2 questionnaires were generally within the average range for both the vermis groups, with the exception of one scale. The group without tumors in the vermis demonstrated elevated difficulties with withdrawal behaviors, which is inconsistent with the stated hypothesis. Overall, it appears that the hypothesis was not supported; however, it is important to note that conclusions cannot be drawn from the descriptive data only.

Hypothesis 4D

This hypothesis stated that participants with CPA in the posterior lobes would perform worse on the executive function tasks than participants with CPA in other areas of the cerebellum. The group with tumors in the posterior lobes consisted of 18 participants; however, seven of these participants also had tumors in the anterior lobes. Children whose tumors invaded the posterior lobes of the cerebellum had means in the average range on all of the executive function tests. The lowest mean score for this group was on the Verbal Fluency Test: Letter Fluency (M = 9.11, SD = 3.36). The group without tumors in the posterior lobes consisted of two participants. Mean scores for children who did not have posterior lobe involvement ranged from borderline to average, with most scores falling in the low average range. Letter-Number Sequencing had the lowest mean score (M = 5.50, SD = 6.36) for this group. Means, standard deviations, medians, and ranges for these variables are reported in Table 22. Given that formal statistical comparisons between the groups were not conducted and that the size of these groups were considerably different, one should not draw conclusions from the means alone.

Exploratory Analyses

In addition to the primary hypotheses, exploratory analyses were performed to further examine behavioral and emotional functioning in the CPA group. These analyses explored whether the other behavioral and emotional scales on the BASC-2 were significantly different from the normative means. The adaptive scales on the BASC-2 were also explored. The tests were two-tailed.

Exploratory Analyses 1: Parent Ratings

The data from the BASC-2 Parent Rating Scale was explored using one-sample t-tests or binomial tests, depending on whether the data were normally distributed. The results of the Shapiro Wilk test were found to be significant for the Aggression ($p = .02$), and Somatization scales ($p = .02$). The Conduct Problems, Internalizing Problems, and Atypicality scales were close to having non-normal distributions. Binomial tests were conducted on the Aggression, Conduct Problems, Somatization, Internalizing Problems, and Atypicality scales and were not found to be significant (Table 23).

The one-sample t-tests on Withdrawal ($p < .01$) and the Behavioral Symptoms Index ($p = .02$) were found to be significant. A trend was observed for Internalizing Problems ($p = .05$). Withdrawal and Behavioral Symptoms Index had medium effect sizes. The means for the clinical scales were generally higher than the normative test mean, which indicate a higher presence of reported difficulties.

The one-sample t-tests on all of the following adaptive scales were found to be significant: Social Skills, Activities of Daily Living, Functional Communication, and Adaptive Skills. Trends were observed for Adaptability ($p = .05$) and Leadership ($p = .05$). Effect sizes, *d*, for the adaptive scales ranged from a small effect of -.46 on Leadership to a large effect of -.80 on Adaptive Skills. The results of the exploratory one-sample t-tests are found in Table 24. On the adaptive scales, lower scores indicate worse functioning. The mean scores from the adaptive scales were lower than the normative test mean of 50.

Overall, the CPA group was found to exhibit significantly more behavioral and emotional problems in the home setting than their peers. Specifically, children surgically treated for CPA demonstrated more withdrawal behaviors and overall behavioral problems. In addition, the CPA group was found to have significantly more problems with several areas of adaptive functioning in the home environment than other children their age.

Exploratory Analyses 2: Teacher Ratings

The data from the BASC-2 Teacher Rating Scale was explored using one-sample t-tests or binomial tests, depending on whether the data were normally distributed. The results of the Shapiro Wilk test were found to be significant for the Aggression ($p = .02$), Conduct Problems ($p = .03$), Externalizing Problems ($p < .01$), Somatization ($p < .01$), Learning Problems ($p < .01$), and Atypicality scales ($p < .01$). The Internalizing Problems and Withdrawal scales were close to having non-normal distributions. Binomial tests were conducted on the scales that were significantly different from a normal distribution or were close to having non-normal distributions. None of the binomial tests were found to be significant (Table 25). Similarly, none of the one-sample t-tests were found to be significant. The effect sizes, *d*, for these tests were small, ranging from -.24 to .02. The results of the exploratory one-sample t-tests are found in Table 26. Overall, the CPA group was not found to exhibit significantly more behavioral, emotional, or adaptive problems in the school setting compared to their peers.

CHAPTER FIVE
Discussion

DISCUSSION OF HYPOTHESES

For many years, children treated for CPA were thought to have minimal cognitive impairment given the cerebellar location of the tumor and its typical treatment consisting of surgical resection with no radiation or chemotherapy. However, research has recently shown that these children display a variety of cognitive problems, such as with intelligence, attention, memory, executive functioning, and visual-spatial skills (Aarsen, Van Dongen, Paquier, Van Mourik, & Catsman-Berrevoets, 2004; Beebe et al., 2005; Karatekin, Lazareff, & Asarnow, 2000). Difficulties with aspects of behavioral and emotional functioning, academic achievement, and adaptive functioning have also been found in pediatric CPA patients (Aarsen, Van Dongen, Paquier, Van Mourik, & Catsman-Berrevoets, 2004; Beebe et al., 2005). Despite the increased focus on cognitive functioning in this population, executive functioning has not been well studied. Previous studies have utilized groups with mixed posterior fossa tumors, have relied on single measures of executive functions, or have had small sample sizes. Given the emerging literature on the cerebellum's role in cognitive functioning and the multidimensionality of executive functions, the current study set out to thoroughly examine executive functioning in pediatric CPA survivors through the use of clinical assessment and behavioral rating scales. As an additional objective, emotional and behavioral functioning were examined through the use of rating scales because of their relevance in cerebellar functioning and their potential impact on executive functioning behaviors.

The primary goal of the current study was to comprehensively examine executive functioning in children who had been surgically treated for CPA. In order to achieve this goal, four primary aims were addressed: 1) to examine the presence of executive function deficits in pediatric CPA, 2) to investigate executive functioning behaviors in the home and school environments and to examine whether observable differences exist between these two settings, 3) to explore behavioral and emotional functioning in the home and school environments and to examine whether observable differences are present, and 4) to determine whether the location of the tumor in the cerebellum has an effect on the type of executive function impaired.

To examine these study aims, 20 individuals between the ages of eight and < 17 years who had been treated for CPA with only surgical resection were administered a multidimensional assessment of executive functions. Parents and teachers of the participants also completed questionnaires pertaining to executive functions and behavioral/emotional functioning. Subjects' performance on these measures was compared to the normative test means, which is common in this type of research. Ratings from the questionnaires were compared to the normative means, and parent and teacher ratings were also compared to each other. The following section will begin with a discussion of the results from this study. Comparisons will be made between the results from the current study and previous cerebellar pathology studies. This will lead to a discussion of theoretical and clinical implications. The section concludes with limitations of the current study and implications for future research.

Results from Hypothesis Testing

Clinical Assessment of Executive Functioning

Based on the literature on cerebellar tumors and lesions, it was hypothesized in the current study that pediatric CPA patients would exhibit problems with the executive functioning components of concept formation, fluency, inhibition, mental flexibility, planning, and working memory. In general, the results showed no significant differences between the performance of the CPA group and the normative test means from the D-KEFS, WCST, and the Working Memory Index and associated subtests on the WISC-IV. However, trends nearing significance were found on Verbal Fluency Test: Letter Fluency, Design Fluency Test: Filled Dots, and Twenty Questions: Initial Abstraction.

Concept formation was assessed with the Twenty Question Test: Initial Abstraction Score, Twenty Question Test: Total Weighted Achievement Score, and WCST: Conceptual Level Responses. The CPA group's means for these measures were within the average range and were not significantly different from the normative test means. However, a trend was observed on Twenty Questions: Initial Abstraction. Both verbal and nonverbal fluency were examined in the current study. In order to assess verbal fluency, Letter Fluency and Category Fluency from the Verbal Fluency Test were utilized. Nonverbal fluency was assessed with Design Fluency Test: Filled Dots, Empty Dots, and Total Correct Composite. No significant differences were found in these tests. Trends nearing significance were found on tests of verbal and nonverbal fluency, specifically Verbal Fluency Test: Letter Fluency and Design Fluency Test: Filled Dots. Overall, effect sizes were small. The Color-Word

Interference Test: Inhibition was used to assess the domain of inhibition. The CPA group's mean score on this test was not significantly different than the normative test mean. Overall, no significant differences were found on the CPA group's performance on subtests measuring the executive function components of concept formation, fluency, and inhibition.

Several subtests assessed the domain of mental flexibility. These included the Trail Making Test: Number- Letter Switching, Verbal Fluency Test: Category Switching, Design Fluency Test: Switching Total Correct, Color-Word Interference Test: Inhibition/Switching, and WCST: Perseverative Responses. No tests were found to be significant and effect sizes were generally small. Planning was assessed with the Tower Test: Total Achievement Score. The CPA group's mean scores were in the average range and were not significantly different from the general population. Working memory was assessed with the WISC-IV Working Memory Index, which is comprised of Digit Span and Letter-Number Sequencing subtests. None of the tests were significant and effect sizes were generally small. Overall, the CPA group's performance on subtests measuring the executive function components of mental flexibility, planning, and working memory was not significantly different from the general population.

In summary, the hypothesis that pediatric CPA survivors exhibit problems with executive functioning on clinical tests of executive functions was not supported. The CPA group's performances on the selected subtests from the D-KEFS, WCST, and WISC-IV were in the average range and were not significantly different from the normative test means. However, trends toward significance were evident on Verbal Fluency Test: Letter Fluency, Design Fluency Test: Filled Dots, Twenty Questions: Initial Abstraction, which are measures of verbal fluency, nonverbal fluency, and concept formation, respectively. Effect sizes for these tests were generally small. Overall, the CPA group's performance on tests measuring concept formation, fluency, inhibition, mental flexibility, planning, and working memory was not significantly different from the normative sample of peers.

Report Measures of Executive Functioning

The CPA group's executive functioning behaviors were examined in the home and school settings through the use of parent and teacher questionnaires. It was hypothesized that parent and teacher ratings on the BRIEF would be significantly higher, i.e., more problematic, than the normative mean. It is interesting that although no significant differences were found in the direct assessments conducted with the children, several areas of their executive functioning were rated as significantly worse than their normal peers. Parents rated the CPA group as exhibiting significantly more difficulties than the general population with their ability to inhibit impulsive responses, adjust to changes in routine, independently initiate activities and problem solving strategies, sustain information in working memory, solve problems in a planned and organized manner, and monitor their own behavior. Effect sizes for these analyses ranged from medium to large. Moreover, the means from the parent ratings were a half standard deviation to greater than one standard deviation above the normative test means. In the school setting, the CPA group was rated as exhibiting more difficulties with sustaining information in their working memory compared to their normal peers. This analysis resulted in a medium effect.

Overall, the CPA group exhibited significantly more difficulties with several areas of executive functioning than their peers based on the parent report. The findings from the BRIEF were not only statistically significant but are also of practical importance given the relatively small sample size in the current study and the resultant medium to large effect sizes. In addition, the means from the parent and teacher ratings were one-half to greater than one standard deviation above the standardized test means. On the BRIEF, T-scores of 65 or greater are considered to be in the clinical range and indicate the presence of a severe problem. While none of the CPA group's mean scores were considered to be in the clinical range, two scales from the Parent Form, Initiate ($M = 63.10$) and Working Memory ($M = 61.15$), fell near the clinical range. It is important to note, however, that although these scores did not fall in the clinical range, they were greater than one standard deviation above the mean.

Parent and teacher ratings were compared to determine if there were differences in the CPA group's executive functioning behaviors in the home and school environments. It was hypothesized that teacher ratings would be significantly higher than parent ratings on the BRIEF, since it was assumed that executive functions were utilized more frequently in the classroom due to the academically and cognitively challenging tasks. However, no significant differences were found between parent and teacher ratings.

Report Measures of Behavioral and Emotional Functioning

The CPA group's behavioral and emotional functioning was examined in the home and school settings through the use of parent and teacher questionnaires. It was hypothesized that parent and teacher ratings of hyperactivity, anxiety, depression, and attention problems on the BASC-2 would be significantly higher, i.e., more problematic, than the normative mean. Depression was found to be significantly higher than the normative test means on the parent forms, but none of the variables above were found to be significant on the teacher forms. Analyses of the parent and teacher ratings on the depression scale resulted in medium effects. On the BASC-2, T-scores of 60-69 are considered at- risk and scores of 70 and greater are considered to be in the clinical range. Behaviors in the clinically significant range suggest that they are severe problems and behaviors in the at-risk range suggest difficulties that have the potential of developing into severe problems. None of these mean scores from the parent and teacher ratings fell in the at-risk or clinical range.

Parent and teacher ratings were then compared to examine whether differences existed between the CPA group's behavioral and emotional functioning in the home and school settings. The hypothesis stated that behavioral and emotional functioning would be significantly higher in the school environment. No significant differences were found between the parent and teacher ratings on the hyperactivity, anxiety, depression, and attention problems scales.

Exploratory analyses were conducted on the remaining clinical scales and the adaptive scales on the BASC-2. Results demonstrated that parents rated the CPA group as having significantly more difficulties with withdrawal and overall behavioral problems than their normal peers. A trend toward significance was found on the internalizing problems scale. Effect sizes for analyses on these scales were medium. No significant differences were found on the teacher ratings. None of the mean scores from the parent and teacher ratings fell in the at-risk or clinical range on the BASC-2.

Interestingly, parents rated the CPA group as having significantly more difficulties compared to norms with several adaptive skills on the BASC-2. These included social skills, activities of daily living, functional communications, and overall adaptive skills. Trends were observed for adaptability and leadership skills. Effect sizes ranged from medium to large. None of the teacher ratings for the adaptive scales were found to be significant. T-scores of 31-40 on the adaptive scales are considered to be at-risk, while scores of 30 and below are in the clinical range. Once again, none of these scores fell in the at-risk or clinical range.

Cerebellar Tumor Location and Executive Functioning

The final aim of the study was to examine whether location of the CPA tumor had an effect on executive functioning and behavioral/emotional functioning. Recent research has suggested the presence of areas of functional localization in the cerebellum. For example, several studies have found that specific types of cognitive and psychological deficits tend to coincide with lesions to certain areas of the cerebellum (Exner, Weniger, & Irle, 2004; Gottwald, Wilde, Mihajlovic, & Mehdorn, 2004; Hokkanen, Kauranen, Roine, Salonen, & Kotila, 2006; Kalashnikova, Zueva, Pugacheva, & Korsakova, 2005; Levisohn, Cronin-Golomb, & Schmahmann, 2000; Molinari, Petrosini, Misciagna, & Leggio, 2004; Riva & Giorgi, 2000; Schmahmann, 1998; Steinlin et al., 2003). In addition, studies on neuroanatomical circuitry indicate that areas within the cerebellar hemispheres are connected with the contralateral cerebral hemisphere (Brodal & Bjaalie, 1997; Dum & Strick, 2003; Heyder, Suchan, & Daum, 2004; Middleton & Strick, 1994, 2000, 2001; Schmahmann, 1991, 2001; Snell, 1997, Voogd, 2003). Based on the previous research, it was hypothesized that CPA in the right cerebellar hemisphere would result in worse performance on language-based executive functions, CPA in the left cerebellar hemisphere would result in worse performance on visual-spatial-based executive functions, and CPA in the vermis would result in more behavioral and emotional problems. An additional hypothesis stated that CPA in the posterior lobes would result in worse performance on measures of executive functioning than CPA in areas other than the posterior lobe. This set of hypotheses was described as "aspirational in nature" from the inception of the study because of the large sample size required to conduct appropriate statistical analyses. In the end, comparison analyses were unable to be conducted given the small sample size in the current study and the very small group sizes when the sample was divided into right hemisphere, left hemisphere, and vermis, or into posterior and anterior cerebellum. Moreover, the majority of participants had tumors that invaded multiple areas of the cerebellum, so they were included into more than one group concurrently. However, participants were divided into dichotomous groups for each comparison (e.g., participants with tumor in the right cerebellar hemisphere versus participants without tumor in the right cerebellar hemisphere). Descriptive statistics were performed and group means and ranges were used to evaluate their performance on the specific domains of executive functioning.

On the language-based executive functioning tasks, the six children with right cerebellar hemisphere tumors had mean scores that ranged from average to high average, while the 14 children with no right cerebellar hemisphere involvement had mean scores in the average range. The twelve children with tumors in the left cerebellar hemisphere had mean scores in the average range on the visual-spatial based executive functions, while the eight children with no left cerebellar hemisphere tumors had scores that ranged from low average to average. Although descriptive statistics are not sufficient for drawing conclusions, it appears that the groups' performance on their respective tasks were not in the hypothesized direction. The range of scores for the right cerebellar hemisphere group on the verbal tasks was slightly higher than for the non-right cerebellar hemisphere group. Similarly, the range of scores for the left cerebellar hemisphere group on the nonverbal tasks was somewhat higher than for the non-left cerebellar hemisphere group. It is worth mentioning, however, that the differences between the mean scores for these groups were small.

It was predicted that participants with tumors that invaded the vermis would exhibit more behavioral and emotional problems. No significant emotional or behavioral problems were noted in children with tumors in the vermis since none of the mean scores for this group fell in the at-risk or clinical range on the BASC-2. However, parent rating on withdrawal behaviors were in the at-risk range for the group of children without tumors in the vermis, which was inconsistent with the hypothesis. Although no specific conclusions should be made without the appropriate analyses, observations of the data suggest that this hypothesis was not supported.

Finally, the 18 children with tumors that invaded that posterior lobe of the cerebellum had mean scores in the average range on the executive functioning tasks. The two children without tumors in the posterior lobes had scores that ranged from borderline to average, with most scores falling in the low average range. This finding is inconsistent with the hypothesis. It is worth mentioning that seven of the children in the posterior group also had tumors invading the anterior lobes. Given the greater cerebellar involvement in the posterior group, it would have been expected that this group would exhibit significantly worse performance on the executive function tasks. However, one should be conservative in the interpretation of these results since the group without posterior lobe tumors was very small.

Summary of Results

The question of whether executive function deficits exist in pediatric CPA survivors was not clearly answered. No significant differences were found between the performance of the CPA group and the normative test means on the executive functioning domains of concept formation, mental flexibility, planning, fluency, inhibition, and working memory. However, trends for worse performance compared to the normative means were found on measures of verbal fluency, nonverbal fluency, and concept formation. Ratings of executive function behaviors in the home setting showed significantly more difficulties with the CPA group's inhibition, shifting, emotional control, initiation, working memory, planning and organization, and monitoring behavior when compared to their normal peers. Ratings of executive function behaviors in the school setting showed significantly more difficulty with working memory. In terms of emotional and behavioral functioning, the CPA group had significantly more difficulties than their normal peers with depression, withdrawal, and overall behavioral problems in the home environment as rated by parents. Interestingly, the group was also found to have significantly more difficulties than the general population with several areas of adaptive skills as rated by parents, specifically, social skills, activities of daily living, and functional communication. Due to a small sample size, comparisons were unable to be conducted between the location of the CPA tumor and the effect on executive functioning and behavioral/emotional functioning. In general, mean scores for the groups fell in the average range, with a few scores that ranged from borderline to high average.

Comparison of Current Results to Previous Research

Cerebellar Pathology

The results of a general lack of executive function deficits in the current study are at odds with previous findings on patients with different types of cerebellar pathology. Impaired verbal fluency, planning, set-shifting, or concept formation have been observed in people with cerebellar ataxias and atrophy, such as spinocerebellar ataxias, cerebellar cortical atrophy, olivopontocerebellar atrophy, Friedreich ataxia, and congenital nonprogressive cerebellar ataxia (Appollonio, Grafman, Schwartz, Massaquoi, & Hallet, 1993; Burk, Bosch, et al, 2001; Burk, Globas et al., 2003; Corben et al., 2006; Grafman et al., 1992; Lilja, Hamalainen, Kaitaranta, & Rinne, 2005; Schmahmann, 2004; Steinlin, Styger, & Boltshauser, 1999). Adults with cerebellar infarcts have also been shown to have impairments in verbal fluency, concept formation, mental flexibility, planning, and working memory (Exner, Weniger, & Irle, 2004; Gottwald, Wilde, Mihajlovic, & Mehdorn, 2004;

Hokkanen, Kauranen, Roine, Salonen, & Kotila, 2006; Kalashnikova, Zueva, Pugacheva, & Korsakova, 2005; Malm et al., 1998; Neau, Arroyo-Anllo, Bonnaud, Ingrand, & Gil, 2000).

The discrepancy between the current results of the CPA study and those of the cerebellar pathology studies may be due to disease and treatment related factors, such as the progressive degeneration of the cerebellum or the inherited genetic mutations that are characteristic of atrophy and ataxia, respectively, or the extent of cerebellar tissue affected by hemorrhage in infarctions. CPA, on the other hand, tend to be more localized and of acute duration. Moreover, there is no cure for hereditary ataxias and some cerebellar atrophies (National Institute of Neurological Disorders and Stroke, 2007), whereas CPA tumors are typically resolved after surgical resection and recurrence is rare (Cohen & Duffner, 1994; Hildenbrand & Baleriaux, 2002; Packer, Friedman, Kun, & Fuller, 2002). Given that the duration of cerebellar affliction is prolonged and that the extent of cerebellar involvement may be greater in different types of cerebellar pathology, it may be that these factors contribute to greater executive function deficits in many other cerebellar pathologies compared to CPA.

A pattern of behavioral changes, termed the cerebellar cognitive affective syndrome (CCAS), has been described in patients with diseases of the cerebellum. This syndrome is characterized by impaired executive functions, visual-spatial skills, personality, and language (Schmahmann, 2004). Although the current study did not attempt to address CCAS, it did examine components of the syndrome, specifically executive and behavioral/emotional functioning. As described above, no deficits in executive function test performance were evident in the CPA group. However, the CPA group was rated as having significantly more difficulties with executive functioning behaviors in everyday life than their normal peers. Conflicting reports of behavioral problems were found in the current study. Parents rated the CPA group as having significantly more behavioral and emotional difficulties than other children their age, while teachers' ratings showed no significant differences between the CPA group and their peers. Although some ratings of executive and behavioral/emotional functioning were significantly higher in the CPA group compared to the normal population, no scores fell in the clinical range, which suggests that these behaviors may not be severely disruptive to the children's lives. Overall, these findings seem to suggest that the significant executive and behavioral/emotional deficits seen in CCAS were not evident in this CPA group. However, mild difficulties in these areas are apparent.

The results of the current study do not fully support the findings from previous studies on adults and children that have shown support for the CCAS (Levisohn, Cronin-Golomb, & Schmahmann, 2000; Malm et al., 1998; Neau, Arroyo-Anllo, Bonnaud, Ingrand, & Gil, 2000; Riva & Giorgi, 2000; Schmahmann & Sherman, 1998). The discrepancy between the findings could be related to disease and treatment related factors given that these studies are comprised of adults with cerebellar and brain stem infarcts, cerebellar cortical atrophy, cerebellitis, and children with different posterior fossa tumors. Moreover, the difference in results may be related to the duration of time elapsed between onset of illness and evaluation. The studies that investigated CCAS conducted most assessments within a few days to a few months following the onset of illness or surgery, with the longest length of time being six years. In the current study, however, children were evaluated an average of seven years after surgery, with a range of one to fourteen years. It is possible that the longer recovery period could result in improvement of deficits that are most apparent during the acute phase. In fact, some studies on patients with cerebellar lesions have shown improvement in cognitive impairments over time (Aarsen, Van Dongen, Paquier, Van Mourik, & Catsman-Berrevoets, 2004; Hokkanen, Kauranen, Roine, Salonen, & Kotila, 2006; Neau, Arroyo-Anllo, Bonnaud, Ingrand, & Gil, 2000).

Executive function deficits have not been consistently found in individuals with cerebellar pathology. Although adults with cerebellar ataxias and atrophy have frequently been shown to exhibit deficits in various components of executive functions (Appollonio, Grafman, Schwartz, Massaquoi, & Hallet, 1993; Burk, Bosch, et al, 2001; Burk, Globas et al., 2003; Corben et al., 2006; Grafman et al., 1992; Lilja, Hamalainen, Kaitaranta, & Rinne, 2005; Schmahmann, 2004; Steinlin, Styger, & Boltshauser, 1999), other studies have reported no difference in executive functioning between adults with cerebellar pathology and their normal peers (Globas et al., 2003; Tanaka, Harada, Arai, & Hirata, 2003). Similarly, some studies on adults with focal cerebellar lesions resulting from hematoma, edema, tumor, or infarction have found impairments in verbal fluency, concept formation, and mental flexibility, while other studies have found these components of executive functioning to be intact (Exner, Weniger, & Irle, 2004; Gottwald, Wilde, Mihajlovic, & Mehdorn, 2004; Malm et al., 1998; Neau, Arroyo-Anllo, Bonnaud, Ingrand, & Gil, 2000). The results of the current study seem to contribute to the conflicting findings of executive function deficits in individuals with insults to the cerebellum. The discrepancy between previous and current results could be explained by disease and treatment related factors, as mentioned previously. Moreover, the disparity in findings could be related to differences in age and recovery potential, i.e., neural plasticity. The majority of participants in the studies on cerebellar pathology ranged from young to older adults, while the participants in the CPA study were typically young children when they were diagnosed and treated, ranging in age from two to eleven years old at the time of surgery. Research has shown that the development of executive functions, frontal lobes, and cerebellum occur in a stepwise manner beginning in early childhood, progressing through late childhood and adolescence, and not reaching full maturity until early adulthood (Anderson, 2001; Diamond, 2000; ten Donkelaar, Lammens, Wesseling, Thijssen, & Renier, 2003; Welsh, Pennington, & Groisser, 1991). In addition, younger age has been associated with improved cognitive outcome in children surgically treated (with no cranial radiation) for cerebellar tumors (Copeland, deMoor, Moore, & Ater, 1999; Levisohn, Cronin-Golomb, & Schmahmann, 2000; Ronning, Sundet, Due-Tonnessen, Lundar & Helseth, 2004). Thus, it could be that the children in the current study were better able to recuperate or compensate for their difficulties because the brain structures involved in executive functioning were not fully developed at the time of the surgery, whereas these structures were already fully developed in the adults in the cerebellar pathology studies. However, this explanation it is not fully supported since other studies of children with CPA and other posterior fossa tumors have suggested deficits in several domains of executive functioning.

Posterior Fossa Tumors

The findings on executive functioning impairments in cerebellar pathology are similar to those in posterior fossa tumors in that inconsistencies abound. Although pediatric posterior fossa tumor patients who have been treated with radiation and/or chemotherapy have been found to display problems with concept formation, mental flexibility, and working memory (Konczak, Schoch, Dimitrova, Gizewski, & Timmann, 2005; LeBaron, Zeltzer, Zeltzer, Scott, & Marlin, 1988; Maddrey et al., 2005), these deficits are confounded by the neurotoxic effects of the radiation and chemotherapy, which result in damage to white matter and other brain structures (American Cancer Society, 2005; Mabbot, Noseworthy, Bouffet, Rockel, & Laughlin, 2006). However, conflicting results regarding the presence of executive function deficits are common in children who have only undergone surgical treatment for posterior fossa tumors. While some studies have shown that these children demonstrate impairments with concept formation, verbal and nonverbal fluency, inhibition, mental flexibility, and working memory, other studies have found these executive functions to be intact (Ater et al., 1996; Levisohn, Cronin-Golomb, & Schmahmann, 2000; Riva & Giorgi, 2000; Steinlin et al., 2003). One major difference between the current study and the posterior fossa tumor studies is the homogeneity of the groups. While the current study consisted of only CPA, these other studies consisted of various posterior fossa tumor types, such as medulloblastoma, ependymoma, astrocytomas, choroid plexus papilloma, gangliocytoma, hemangioblastoma. Moreover, posterior fossa tumors were not confined to the cerebellum, but also included structures in the brain stem. Given the different tumor growth rates and response to treatment and the varied posterior fossa locations in the previous studies, it is difficult to determine if the discrepancies in results were due to damage to the cerebellar circuits involved in executive function or to other factors, such as involvement of other brain structures. The heterogeneity of tumor type and location included in previous studies also make direct comparison to the present study difficult. As discussed in the literature review, heterogeneity of tumor type and location have long been a limiting factor in terms of being able to determine conclusive findings from many earlier studies of neurocognitive outcome following various types of brain tumor. The current study is an improvement over previous studies because of the homogeneous CPA sample.

Up to now, the differences in results between the current and previous studies have been assumed to be associated to factors involving disease, treatment, recovery, and age. However, a very small number of studies have focused on executive functions specifically in children surgically treated for CPA. The studies that have been conducted have found problems with the concept formation and mental flexibility components on the WCST, but other measures of mental flexibility have been normal (Aarsen, Van Dongen, Paquier, Van Mourik, & Catsman-Berrevoets, 2004; Karatekin, Lazareff, & Asarnow, 2000). No problems with verbal fluency and planning were observed (Aarsen et al., 2004). The current study is fairly consistent with the previous findings of a lack of problems in the executive function domains of verbal fluency and planning. Moreover, it builds upon these findings by adding that nonverbal fluency, inhibition, and working memory in pediatric CPA survivors are also similar to their normal peers.

The WCST was administered in the current battery since it is frequently used in studies as the primary measure of executive function. Previous pediatric CPA studies have reported problems with concept formation and mental flexibility on the WCST. Karatekin, Lazareff, & Asarnow (2000) used the WCST to investigate executive functions in four CPA patients. Findings from the Karatekin et al. (2000) study should be interpreted cautiously since the study had an extremely small CPA group. In addition, formal statistical analyses were not used to evaluate the group's performance. Rather, scores from the patients' IQ scores were compared to their WCST scores, and differences of one to two standard deviations were considered significant. In the Karatekin et al. study, examination of the CPA group's performance on concept formation showed that two participants obtained scores that were considered to be "within normal limits," whereas the other two participants' scores fell in the low average and borderline range. The authors reported that the CPA group's performance on mental flexibility was in the low average range. In contrast, the current study found that the CPA group's performance on concept formation and mental flexibility on the WCST was in the average range. In another CPA study, Aarsen, Van Dongen, Paquier, Van Mourik, and Catsman-Berrevoets (2004) compared a pediatric CPA sample's performance to the normative data on the Wisconsin Modified Card Sorting Test (WMCST), a shortened version of the WCST. The authors found that the group's performance on concept formation and mental flexibility was significantly below the normative test mean. However, the group's scores on these executive function components were less than one standard deviation below the normative test mean and were still within the average range. Although the CPA group's performance in the Karatekin et al. study ranged from the average to borderline range on concept formation and mental flexibility, the group scores from Aarsen et al. (2004) and the current study all fell within the average range of functioning. In general, contradictory findings in terms of statistical significance on the WCST are observed between previous and current CPA studies. However, the performance of most CPA patients on concept formation and mental flexibility generally falls within the average range.

The results of the current study suggest that deficits in concept formation, fluency, inhibition, mental flexibility, planning, and working memory in pediatric CPA survivors are not a routine finding. Although deficits in various executive function components have been reported in cerebellar diseases, lesions, and tumors, these deficits do not seem to be characteristic of children surgically treated for CPA. Interestingly, although no significant differences were found on the CPA group's performance on tests of executive function, a large number of concerns were noted on the parent ratings on the BRIEF. The incongruence between test results and parent ratings could be due to a number of factors. First, pediatric CPA patients might exhibit subtle executive function difficulties, which the neuropsychological tests might not be sensitive enough to detect. Parents may be most sensitive to executive function changes in their child. Despite the many significant findings on the BRIEF parent ratings, teachers only rated working memory as being significantly worse. Perhaps the difference between parent and teacher ratings has to do with teachers having so many children in class that they are not as sensitive as parents. However, it should not be discounted that the higher parental ratings could also be a sign of parent distress secondary to having a child with brain tumor. Furthermore, the lack of significant findings in the test results could be due to limited power in the current study. As mentioned previously, power analyses indicated that a sample size of 20 participants would provide 80% power to detect an effect size of d = .58; however, most of the effect sizes for one-sample t-tests on the clinical measures were small.

Psychological Functioning

Different types of behavioral and emotional problems have been reported in cerebellar pathology literature. Standardized questionnaires have been utilized in some studies to screen for behavioral and emotional problems, whereas many other studies have relied upon parent or examiner reports and observations. A number of studies on patients with cerebellar atrophy, infarction, and cerebellitis have found disinhibition, affective problems, and withdrawal behaviors (Exner, Weniger, & Irle, 2004; Gottwald, Wilde, Mihajlovic, & Mehdorn, 2004; Schmahmann & Sherman, 1998), while other studies have reported no depressive behaviors (Appollonio, Grafman, Schwartz, Massaquoi, & Hallet, 1993; Neau, Arroyo-Anllo, Bonnaud, Ingrand & Gil, 2000). Mixed results have also been observed in pediatric posterior fossa tumor patients, with some studies reporting problems with affective functioning, behavioral disturbance, impulsivity, and social interactions (Copeland, deMoor, Moore, & Ater, 1999; LeBaron, Zeltzer, Zeltzer, Scott, & Marlin, 1988; Levisohn, Cronin-Golomb, & Schmahmann, 2000; Riva & Giorgi, 2000; Steinlin et al., 2003), while other studies report no significant differences from their normal peers (Ater et al., 1996; Copeland, deMoor, Moore, & Ater, 1999; Maddrey et al., 2005). In children surgically treated for CPA, studies have reported problems with depressive behaviors, anxiety, attention problems, and behavioral disturbances (Aarsen, Van Dongen, Paquier, Van Mourik, & Catsman-Berrevoets, 2004; Beebe et al., 2005). The current study had similarities to previous studies given that the CPA group was rated as having significantly more difficulties with depression, withdrawal, and overall behavioral problems when compared to their normal peers. The behavioral and emotional difficulties in this study were not considered to be clinically problematic. Similarly, other studies on pediatric CPA patients have found significant differences on behavioral questionnaires, but these scores have not been in the clinical range (Beebe et al., 2005). Unfortunately, most of the studies above that utilized standardized behavioral questionnaires did not list scores, so it was not possible to determine whether the mean scores in these studies fell into the clinical range.

As mentioned above, some studies have found problems in behavioral and emotional functioning in people with different types of cerebellar pathology, while other studies have noted no concerns. One possible reason for the discrepancy between studies could be the different methods that have been employed to examine whether these problems exist. For instance, some studies above have used parent interviews, while others have used behavioral rating scales completed by parents, informal observation of child's behavior during testing, or reviews of patient records to determine the presence and severity of behavioral and affective problems. Given the wide variety of methods used to identify whether behavioral and emotional problems exist, the accuracy and reliability of detecting clinical problems across the studies is not standardized and therefore may not support a consistent conclusion. The differences in findings relating to behavioral/emotional functioning between previous and current studies could also be due to psychosocial factors, such as the patients' adjustment to their illness and treatment, the impact of their disease on their family and everyday life, and the individual's support from family and friends. However, these factors were not examined in the studies above. Furthermore, the differences in results between studies may be related to the duration of time elapsed between surgery and evaluation. It may be that issues with behavioral and emotional functioning were more prominent in the acute phase and partially resolved over time. However, differences between acute and long term behavioral/emotional functioning were not addressed in the studies above.

Interestingly, exploratory analyses on the BASC-2 Parent Rating Scale showed that the CPA group exhibited significantly more difficulties than the general population in overall adaptive skills, such as social skills, activities of daily living, and functional communication. A recent study that investigated adaptive functioning in children surgically treated for CPA using the Vineland Adaptive Behavior Scales also found problems with communication, social, motor, and overall adaptive skills, but no significant differences were noted with daily living skills (Beebe et al., 2005). Most of scores from the Vineland Adaptive Behavior Scales were in the average range with the exception of motor skills, which fell in the low average range. Similarly, the adaptive skills ratings in the current study were in the normal range. The authors explained that problems with adaptive skills were not explained by pre-, peri-, or post-surgical medical complications (for example, hydrocephalus, seizures, level of consciousness, CNS infections, hematoma, etc), cerebellar tumor location, or demographic factors. Motor deficits were thought to play somewhat of a role in the problems with adaptive functioning. The authors concluded that children who have undergone surgical resection of CPA are at an elevated risk of poor adaptive functioning. Although the current study did not formally assess motor functioning, half of the parents reported that their children had difficulties with motor development, current physical abilities, and/or a history of occupational/physical therapy. It is possible that the differences in adaptive functioning observed in the current study could be related to motor problems, delays due to lengthy medical illness, or prolonged absences from school and social activities.

Location Specific Effects

Unfortunately, the sample size in this study was too small to determine the impact of tumor location on executive functioning. Previous studies on cerebellar lesions resulting from infarcts or tumors have reported that each cerebellar hemisphere processes cognitive functions that are associated with the contralateral cerebral hemisphere. Verbal skills are processed in the right cerebellar hemisphere, visual-spatial skills are processed in the left cerebellar hemisphere, and overall cognitive functions appear to be mediated by the posterior lobes of the cerebellum. In addition, behavioral and emotional functions appear to be mediated by the vermis (Exner, Weniger, & Irle, 2004; Gottwald, Wilde, Mihajlovic, & Mehdorn, 2004; Hokkanen, Kauranen, Roine, Salonen, & Kotila, 2006; Kalashnikova, Zueva, Pugacheva, & Korsakova, 2005; Levisohn, Cronin-Golomb, & Schmahmann, 2000; Molinari, Petrosini, Misciagna, & Leggio, 2004; Riva & Giorgi, 2000; Salman, 2002; Schmahmann & Sherman, 1998; Steinlin et al., 2003).

The majority of the children in the current study had tumors that invaded multiple cerebellar areas, so there was much overlapping between the groups (right hemisphere, left hemisphere, and vermis; posterior and anterior cerebellum). The small sample size also restricted the type of analyses that could be conducted to compare the groups. The sample was divided into dichotomous groups (e.g., participants with CPA in the right cerebellar hemisphere versus participants with no CPA in the right cerebellar hemisphere) and descriptive statistics were used instead to examine the data. In general, the group means were not in the expected direction. The range of mean scores for the right cerebellar hemisphere group and left cerebellar hemisphere group were slightly higher on the verbal and nonverbal tasks, respectively. Similarly, the posterior cerebellar group had higher mean scores than the group without posterior lobe tumors. No behavioral or emotional problems were evident based on the mean scores of the vermis group; however, mean parent ratings on the Withdrawal scale on the BASC-2 fell in the at-risk range for the group without tumors in the vermis. It is important to note that these are descriptions of means and not results of statistical analyses. Although these findings appear to be at odds with previous results, it is difficult to determine the specific cause of the discrepancy given the widespread cerebellar involvement seen in most participants in the current study. However, one would expect that more extensive cerebellar damage would result in worse performance on the executive function tasks, but this was not the case in this study. Clearly this is an area that warrants further investigation

Theoretical Implications

The cerebellum has long been known to play a primary role in the control of movement and posture, but recent findings have shown that the cerebellum is also implicated in various aspects of cognitive, behavioral, and emotional functioning. The cerebellum has been implicated in a set of complex cognitive skills, termed executive functions, which have historically been attributed to the frontal lobes. The actual role of the cerebellum in these functions, however, is unclear, as some studies on patients with cerebellar lesions report considerable deficits while other studies find no significant differences (Aarsen, Van

Dongen, Paquier, Van Mourik, & Cateman-Berrevoets, 2004; Ater et al., 1996; Exner, Weniger, & Irle, 2004; Gottwald, Wilde, Mihajlovic, & Mehdorn, 2004; Kalashnikova, Zueva, Pugacheva, & Korsakova, 2005; Karatekin, Lazareff, & Asarnow, 2000; Levisohn, Cronin-Golomb, & Schmahmann, 2000; Malm et al., 1998; Riva & Giorgi, 2000; Steinlin et al., 2003). The cerebellum's role in executive functioning has also been supported by findings from neuroimaging and neuroanatomical studies, which have provided greater understanding of the reciprocal cerebrocerebellar system in which interconnections are found between the cerebellum and the prefrontal cortex (Allen, McColl, et al., 2005; Brodal & Bjaalie, 1997; Desmond, Gabrieli, Wagner, Ginier, & Glover, 1997; Dum & Strick, 2003; Garavan, Ross, Li, & Stein, 2000; Heyder, Suchan, & Daum, 2004; Middleton & Strick, 1994, 2000, 2001; Schmahmann, 2001; Schmahmann & Pandya, 1995; Schmahmann & Pandya, 1997). The findings from the current study, however, do not suggest that surgical resection of CPA tumors significantly negatively affects performance on tests of executive functions. It might be expected that the CPA group in this study would have exhibited measurable executive function impairments given that the majority of children had multiple cerebellar areas affected and that there was a very high percentage of children who had tumors located in the posterior lobes, an area of the cerebellum that has been closely linked to cognitive functioning. Furthermore, it was hypothesized that significant compromise would occur because CPA tumors press on the cerebellum and create a mass effect along with complications such as hydrocephalus. However, the test results suggest that no significant executive function deficits were evident. It may be that this pathology does not create nearly as much compromise in cerebellar function as one might have presumed given that CPA are well-encapsulated tumors that push against the cerebellum rather than infiltrate cerebellar tissue. However, further research is needed to elucidate the cerebellum's contribution to executive functioning.

Since there was not a pattern of dysfunction that was detected on the tests of executive functions, it is difficult to comment on the differential functions of the cerebellum itself. However, it may be that surgical resection of CPA tumors in children results in subtle and mild executive function weaknesses, which these tests are not able to detect. Parent questionnaires, such as the BRIEF, may be more sensitive to problems with executive functioning in daily life. It is interesting to note that although no problems with executive functions were found on the clinical measures in the current study, parent ratings from the BRIEF showed that the CPA group exhibited significantly more difficulties with inhibiting impulsive responses, adjusting to changes in routine, modulating emotions, independently initiating activities and problem-solving strategies, sustaining information in working memory, solving problems in a planned and organized manner, and monitoring their behavior compared to normal functioning peers. The results from the BRIEF parent questionnaires appear to be consistent with findings from previous cerebellar pathology studies of problems with various components of executive functions. For instance, elevated scores on the BRIEF Shift scale indicated that the CPA group exhibited significantly more problems with their ability to adjust to changes in routine or with transitioning from one topic to another compared to the normative sample of peers, which relates to problems with the everyday behaviors of mental flexibility. Higher scores on the Inhibit scale suggested more difficulty with appropriately stopping behavior than normal functioning peers, which is associated with weak inhibition. Elevated scores on the Plan/Organize scale indicated that the CPA group had more difficulty than the normative sample of peers when completing tasks in a systematic manner, which relates to weaknesses in the executive function domain of planning. The higher scores on the Initiate scale, which indicated that the CPA group had greater difficulty with generating ideas and problem-solving strategies compared to normal functioning peers, might be representative of difficulties with concept formation and fluency. In addition, both teacher and parent ratings showed significantly more difficulties compared to the general population on the Working Memory scale, which assesses a child's ability to hold information in their mind in order to complete an activity. Overall, parent ratings from the BRIEF suggest that pediatric CPA patients exhibit subtle problems with concept formation, fluency, inhibition, mental flexibility, planning, and working memory in their daily lives.

As mentioned before, several reasons might explain the differences between parent ratings from the BRIEF and the results from the clinical tests. For example, parents might be the most sensitive observers of their children's executive functions given that parents are around their children more than anyone else. While we might think that the educational setting taps executive functions more than other aspects of a child's life, it may be that teacher ratings are somewhat muted simply because they have so many children to observe. Teachers may not be as sensitive as parents to some of the subtle nuances and changes in executive functions that an individual child with CPA might exhibit. Although it is also possible that the elevated scores on the BRIEF may be due to parents having expressed a more general, nonspecific distress based on their child having a life threatening and unusual medical illness, these findings appear to be more in line with subtle and mild executive weaknesses.

Given the multiple areas of concern noted on the BRIEF parent questionnaires, there is indication that there may be more going on with the CPA group's executive functioning than is reflected in the direct test results. It is possible that executive functioning problems exist in the CPA group that were simply not captured by the tests, and this may reflect more on the limitations inherent in tests, such as issues with test sensitivity and ecological validity. It may be that current test instruments are not sensitive enough to capture mild executive function weaknesses, and the generalizability of test results to daily life may be weaker than expected, such that performance on executive function tasks in the clinic setting may not fully translate to performance of executive function behaviors in everyday situations. It is important to mention, however, that evaluation of executive functions is a difficult task. The construct of executive functions is multidimensional and currently there is no uniform or unitary conceptualization of executive functions. As such, there is no agreed upon universal test of executive functioning that has proven ecologically valid. Moreover, the inherent structure and support offered in a one-to-one testing setting may not be reflective of executive function demands present in everyday life. Even though there have been numerous refinements of older tests and development of several new tests, the ecological validity of current executive function tests for children is still a work in progress. Therefore, it is important that researchers and clinicians continue to theorize about the component cognitive functions that make up executive functions in order to develop a more unitary conceptualization of the construct and component functions. In addition, more information is needed about the development of executive functions in children and how these behaviors are exhibited in daily life. Further research is needed on how to construct tests that will be more sensitive to executive function problems and on how to test these functions in an ecologically valid manner. Moreover, as further knowledge is gained about the contribution of the cerebellum to executive functioning, tests that are sensitive to the cerebellar influence on these functions should be developed and validated.

Clinical Implications

The lack of executive function deficits on clinical measures does not necessarily mean that there are no problems, since issues with sensitivity and ecological validity of the tests can affect whether these skills are adequately assessed (Baron, 2004). Therefore, an important aspect to consider in the assessment of executive functions in children is clinical test development and test selection. By using tests that tap into the various components of executive functions, we gain a better understanding of the child's overall problem-solving and goal directed behaviors, which allow for more knowledgeable interpretations and judgments of the child's behavior in other settings. The current study attempted to address this issue by utilizing a comprehensive battery of executive function tasks, which assessed the dimensions of concept formation, fluency, inhibition, mental flexibility, planning, and working memory. In addition, parent and teacher questionnaires were used to evaluate executive functions across the home and school settings. However, current tests are not without limitations. Executive function tests for children have historically been extensions of adult tests, rather than tests based on child development principles (Baron, 2004). Thus, the construction of developmentally sensitive tests are necessary in order to better assess children's emerging and maturing skills. In addition, measures of executive function should have good ecological validity, so that results from the clinical assessments are generalizable to the child's daily functioning. The current study attempted to address these issues by utilizing parent and teacher versions of the BRIEF, a rating system of overt behaviors in everyday situations that is based on theory and research of executive function development in children. As new tests that are developmentally appropriate, well normed, and ecologically valid are constructed, we will be better able to capture the breadth of executive functions in children. Moreover, as tests are further developed and refined, perhaps they will be more sensitive and maybe pediatric CPA patients will have their real deficits elucidated.

It is important to take the findings from the current and previous studies into consideration when determining whether a neuropsychological evaluation is warranted, since a variety of acute and long-term problems have been found to exist in children following surgical resection of CPA and other posterior fossa tumors. Clinicians should be cognizant of these difficulties and inform parents to be watchful of problems in cognitive, behavioral, emotional, adaptive, and academic functioning. If a child is referred for an evaluation, it may not be necessary to complete a comprehensive evaluation of executive functions on each pediatric CPA patient. However, parent and teacher questionnaires, such as the BRIEF, should be frequently utilized to screen for executive function problems since these may capture subtle difficulties in everyday functioning that would otherwise not be observed in the clinical setting. Behavioral and emotional questionnaires, such as the BASC-2, should also be provided to parents and teachers to check for problems since the current and previous studies have reported a number of difficulties in these areas. Studies on CPA patients have typically employed one or two measures to assess executive functions; however, as has been described throughout this project, executive functions are multidimensional and the full range of executive functions cannot be adequately measured without broad, multidimensional assessment. If concerns are noted on executive function questionnaires or if possible difficulties are disclosed during the clinical interview, then a multidimensional approach to assessment of executive functions is recommended. Test batteries such as the D-KEFS allow for a comprehensive evaluation and alternate forms of the Sorting, Verbal Fluency, and Twenty Question subtests also allow for re-evaluation with reduced practice effects. Although the tests and questionnaires above provide useful information of a child's strengths and weaknesses, one should always bear in mind the limitations inherent in testing in a clinical setting.

Executive functions are very important to a child's functional success since they play a large role in a child's cognitive efficiency, ability to solve problems, complete goals, and direct behavior. Thus, problems with executive functions can have negative ramifications on a child's academic, psychological, and social functioning. Identifying problems is the first step toward effective intervention. Utilizing measures that are able to accurately capture a wide range of difficulties and which are generalizable to everyday life is the key. Therefore, evaluations should examine the various components of executive functions and incorporate information from parent and teacher ratings. A multidimensional and multi-setting assessment of executive functions would allow for a greater probability of identifying both overt and subtle problems with a child's daily executive functioning skills. With this information, interventions targeting problems within specific domains of executive functioning can be adapted for each child. Moreover, academic support systems can utilize this information about the child's executive functioning problems to develop more individualized and effective educational plans.

Limitations of the Current Study and Future Directions

Although the current study was designed to address some limitations in previous studies and expand upon prior research, there were still several limitations in this study. One limitation was that of sample size. The relatively small sample size in the current study limited the type and power of analyses that were conducted. Original estimates of power showed that 27 participants would be needed in order to detect a difference of one-half standard deviation at $p = .05$. Moreover, nonparametric analyses were often utilized since the assumptions for parametric tests were not always met. The small sample size also restricted the analyses in regards to cerebellar localization of executive functions. When the total sample was divided into the different cerebellar location groups, some groups contained less than 10 participants. Moreover, there was much overlap between the groups because most participants had tumors that invaded multiple cerebellar regions. Ultimately, it was not possible to adequately examine this aim. Previous studies have addressed the issue of small sample sizes by utilizing heterogeneous groups comprised of different cerebellar diseases or tumor types; however, an explicit purpose of this study was to avoid the limitations inherent in heterogeneous groups.

Given the difficulty in this study of recruiting a large sample for such a specific population, future studies on children with CPA should be conducted across multiple sites so as to increase overall sample size. Future studies should further investigate the executive function components of concept formation, verbal fluency, and nonverbal fluency. Given that trends toward significance were evident in the current study, which had limited power, a larger sample size would provide greater power for the analyses. Furthermore, future studies utilizing a significantly larger sample size of pediatric CPA survivors would also allow for more detailed examination of the effect of cerebellar tumor location on verbal and nonverbal executive functions and on behavioral/emotional functions. It will be very important for future studies to maintain homogeneity in terms of tumor types, as including multiple tumor types is a significant limitation that has plagued pediatric brain tumor outcomes research for years. A considerably larger number of participants would permit for comparisons between groups with localized tumors in the right cerebellar hemisphere, left cerebellar hemisphere, and vermis, as well as between groups with posterior and anterior cerebellar tumors. Studies should also examine differences in executive and behavioral/emotional functioning between children with more extensive cerebellar tumor involvement versus children with localized tumors to gain a better understanding of the impact of lesion size. Additionally, functional neuroimaging studies could be conducted to investigate differences in cerebellar activation during cognitive tasks in individuals with cerebellar lesions and healthy controls. Overall, more studies are needed to gain a more detailed understanding of the cerebellum's role in the neural network of executive functioning.

In addition, future studies should investigate whether age at surgery and time since surgery have an effect on executive and behavioral/emotional functions. Stratified samples of different aged children should be studied longitudinally in order to examine the acute and long-term effects of lesions to the cerebellum. Ideally, a repeated measures design in which pre- and post-surgical evaluations are conducted on these samples could be incorporated into future studies in order to examine the direct impact of surgical resection of cerebellar tumors. It would also be interesting to evaluate adults who underwent CPA tumor resection during childhood to determine whether there are permanent differences in the developmental trajectory of executive and behavioral/emotional functioning in CPA survivors.

Difficulty encountered with specific data collection was also a limitation of the study. The participants' math and English teachers were provided with two behavioral questionnaires to complete, but many teacher questionnaires were not received despite reminder phone calls and emails. In total, 14 out of the 20 participants had at least one teacher who completed and returned the questionnaires; however, only a total of seven participants had all teacher questionnaires completed. A possible reason for the low teacher participation was that data was collected during the summer months when some teachers were not on campus. However, school personnel often contacted the teachers to inform them of the questionnaires. Numerous attempts to collect the data after the new school year commenced resulted in a few additional teacher questionnaires. An additional problem with the teacher questionnaires had to do with methodological design. The study asked for Math and English teachers to complete the rating scales in order to obtain multiple teacher perspectives and to observe executive and behavioral/emotional functioning in different academic environments that require different cognitive demands. However, some of the younger children had one classroom teacher who taught all subjects. This initially created a problem in data analysis, since there were children with one set of questionnaires and other children with two sets of questionnaires. Ultimately, all teacher questionnaires were combined into one category, irrespective of type of teacher. When two teacher questionnaires were available for one participant, which occurred with four participants, then one teacher questionnaire was randomly chosen to be excluded from the analyses. This was done in order to avoid over-representing these children in the analyses. Most studies on CPA patients examine functions of interest through the use of clinical measures and/or parent ratings, but it is less common to incorporate teacher ratings. Given the impact of problems with executive, behavioral, and emotional functioning on a child's academic progress, it is important to gain a broader understanding of the child's abilities and weaknesses in the school setting. Therefore, future studies should make an effort to employ teacher ratings as an additional source of information, even though this comes with a unique set of practical challenges in terms of data collection.

A limitation of study could also pertain to the tests utilized in the current study. As mentioned previously, even though new tests have been developed and older tests have been refined, the sensitivity and generalizability of these new tests may not be as favorable as expected. As has been the case in previous research with executive functions, it may be that the current tests do not adequately capture these skills in a lab setting. Future studies should continue to focus on the construct of executive functions and the component cognitive functions that comprise it in order to derive a more coherent conceptualization. In addition, there should be further development and refinement of methods by which executive functions are measured in an ecologically valid manner. Furthermore, tests that are sensitive to cerebellar influence on executive functioning should be developed as further knowledge is gained about the cerebellum. Examinations of the relationship between clinical test results and BRIEF parent and teacher ratings should also be conducted in order to determine whether differences exist between the measures' ability to identify problems with executive functioning.

Another limitation pertained to the lack of a control group in the current study. Ideally, the addition of a control group would have allowed for comparison of the CPA group to a group of age and of gender matched healthy children. Given the nature of this study, it was not feasible to recruit and evaluate a comparison group of normal children; however, not utilizing a comparison group is a common experimental design in pediatric brain tumor outcome research. The CPA group's performance was instead compared to the normative test sample, a standard practice in this line of research (Aarsen, Van Dongen, Paquier, Van Mourik, & Cateman-Berrevoets, 2004; Ater et al., 1996; Beebe et al., 2005; Steinlin et al., 2003; George et al., 2003). Moreover, the question has been raised as to whether an appropriate control group exists for childhood cancer survivors, given the unique factors such as invasiveness of treatment and extensive school absences. This has led to the recommendation that the performance of these patients be compared to the normative sample (Krull, 2006). Future studies, however, should consider utilizing control groups comprised of healthy children matched on specific variables, such as age and gender. Clinical control groups comprised of children with other intracranial tumors with similar growth rate and treatment modality could also be utilized for comparison, although the functional differences in tumor location and treatment and disease related factors could make interpretation and generalization of the results difficult.

CONCLUSION

The primary purpose of the current study was to thoroughly examine executive functions and to explore behavioral and emotional functioning in children surgically treated for CPA. It was predicted that the CPA group would exhibit poor performance on executive function measures of concept formation, verbal and nonverbal fluency, inhibition, mental flexibility, planning, and working memory. Parent and teacher ratings of executive and behavioral/emotional functioning were expected to demonstrate higher levels of problems. Furthermore, ratings for behaviors in the school setting were hypothesized to be worse than the school environment. Finally, location of tumor within the cerebellum was predicted to impact the type of executive function affected.

Overall, no significant deficits were found on any of the clinical measures of executive functions. The CPA group's performance was not significantly different from the normative test mean on the D-KEFS, WCST, and Working Memory Index and associated subtests on the WISC-IV. Conversely, parent ratings on the BRIEF demonstrated significantly more difficulties with shifting, inhibition, emotional control, initiation, working memory, planning and organization, and monitoring of behavior. Composite scores for the Behavioral Regulation Index, Metacognition Index, and Global Executive Composite also showed significantly more difficulties. The only significant finding on the BRIEF Teacher Form was with working memory. In terms of behavioral/emotional functioning, parent ratings on the BASC-2 showed significantly more difficulties with depression, withdrawal, and overall behavior problems when compared to peers, whereas teacher ratings showed no significant problems. Parents also reported significantly more difficulties compared to the norms with adaptive skills, including social skills, activities of daily living, and functional communication; however, teacher ratings of adaptive skills were not significant. Cerebellar localization was unable to be examined given the small sample size in the study.

Overall, these results suggest that significant executive function deficits may not be as common in pediatric CPA survivors as some previous studies have suggested; however, it appears that these children may exhibit subtle and mild weaknesses in the performance of executive function behaviors in daily life. Moreover, these children also appear to be at risk for problems with behavioral, emotional, and adaptive functioning. It appears that surgical resection of CPA in children does not result in as much compromise in cerebellar function as was once thought. It may be that there is less tissue damage given that CPA tumors press on the cerebellum rather than infiltrate cerebellar tissue. It is also possible that the tests used are not as sensitive to the subtle difficulties in executive functions that the pediatric CPA patients exhibited. Overall, a multidimensional and multi-setting assessment of executive functions, consisting of both clinical tests and parent and teacher questionnaires, allows for greater likelihood of detecting both subtle and overt problems with children's overall problem-solving and goal-directed behaviors.

Table 1

Neuropsychological Measures

Test Variable	Normative Mean (SD)	Type of Measure
Wechsler Abbreviated Scale of Intelligence (WASI; The Psychological Corporation, 1999)		
Full Scale IQ-2	100 (15)	V/NV
Delis-Kaplan Executive Function System (D-KEFS; Delis, Kaplan, & Kramer, 2001)		
Trail Making Test		
Number- Letter Switching	10 (3)	NV
Verbal Fluency Test		
Letter Fluency: Total Correct	10 (3)	V
Category Fluency: Total Correct	10 (3)	V
Category Switching: Total Correct Responses	10 (3)	V
Design Fluency Test		
Filled Dots: Total Correct	10 (3)	NV
Empty Dots: Total Correct	10 (3)	NV
Switching: Total Correct	10 (3)	NV
Design Fluency Total Correct	10 (3)	NV

(table continues)

Table 1 (cont.)

Test Variable	Normative Mean (SD)	Type of Measure
Color-Word Interference Test		
Inhibition	10 (3)	V/NV
Inhibition/Switching	10 (3)	V
Twenty Questions Test		
Initial Abstraction Score	10 (3)	V/NV
Total Weighted Achievement Score	10 (3)	V/NV
Tower Test		
Total Achievement Score	10 (3)	NV
<u>Wisconsin Card Sorting Test</u> (WCST; Heaton, Chelune, Talley, Kay, & Curtis, 1993)		
Conceptual Level Responses	50 (10)	NV
Perseverative Responses	50 (10)	NV
<u>Wechsler Intelligence Scale for Children – Fourth Edition</u> (WISC-IV; Wechsler, 2003)		
Working Memory Index	100 (15)	V
Digit Span	10 (3)	V
Letter-Number Sequencing	10 (3)	V

Note. V = Verbal/language-based measure. NV = Nonverbal/visual-spatial-based measure. V/NV = Contains both verbal and nonverbal elements in the measure.

Table 2

Descriptive Statistics of Medical Information

Variables	All Subjects			
	M	SD	Median	Range
Age at diagnosis (years)	5.40	1.90	5.13	2.58-11
Time from diagnosis/surgery to evaluation (years)	7.40	3.07	7.29	1.17-14.08
		n	%	
Pre/Post-operative conditions				
Hydrocephalus		14	70	
Shunt insertion only		4	29	
Ventriculostomy only		5	36	
Shunt insert and ventriculostomy		3	21	
Type of resection				
Gross total resection		16	80	
Subtotal resection		4	20	

(table continues)

Table 2 cont.

Variables	Subjects with tumor [n (%)]
Total Tumor Combinations	
Left Anterior, Left Posterior	1 (5%)
Left Anterior, Left Posterior, Vermis Anterior, Vermis Posterior	1 (5%)
Left Posterior	6 (30%)
Left Posterior, Vermis Posterior	2 (10%)
Right Anterior, Left Anterior, Vermis Anterior, Vermis Posterior	1 (5%)
Right Anterior, Left Anterior, Vermis Anterior	1 (5%)
Right Posterior	1 (5%)
Right Posterior, Vermis Anterior, Vermis Posterior	1 (5%)
Right Posterior, Vermis Posterior	2 (10%)
Vermis Anterior	1 (5%)
Vermis Anterior, Vermis Posterior	3 (15%)
Total	20 (100%)

Note. The cerebellum was divided into six areas: right anterior, right posterior, left anterior, left posterior, vermis anterior, and vermis posterior. Most participants had tumors that invaded multiple cerebellar areas.

Table 3

Descriptive Statistics of Historical Information

Variables	n (%)		
	Below Average	Average	Above Average
Motor development	6 (30%)	10 (50%)	4 (20%)
Speech/language development	4 (20%)	13 (65%)	3 (15%)
Current academic performance	6 (30%)	8 (40%)	6 (30%)
		Yes	No
History of occupational/physical therapy		7 (35%)	13 (65%)
History of speech/language therapy		6 (30%)	14 (70%)
History of learning problems		4 (20%)	16 (80%)
Early Childhood Intervention/Preschool Program for Children with Disabilities		3 (15%)	17 (85%)
History of special education services		9 (45%)	11 (55%)
History of behavioral/emotional problems		10 (50%)	10 (50%)

Table 4

Shapiro-Wilk and Binomial Tests for Hypothesis 1A: Delis-Kaplan Executive Function System

Variable	Shapiro-Wilk Test		Binomial Test				
	Statistic	*p* value	Median (Range)	Observed Proportion		*p* value	Effect Size (*g*)
				Scores ≤ 10	Scores > 10		
Verbal Fluency Test							
Category Switching	.90	.04	8.50 (5-15)	.65 (13)	.35 (7)	.13	.15
Twenty Questions							
Initial Abstraction	.91	.06	8.50 (6-16)	.70 (14)	.30 (6)	.06	.20
Total Weighted Achievement	.84	<.01	11.00 (2-13)	.45 (9)	.55 (11)	.41	-.05
Design Fluency							
Empty Dots	.93	.13	9.00 (5-14)	.55 (11)	.45 (9)	.41	.05

Note. The test proportion was set at .50. The cut point was the mean of 10.

Table 5

Shapiro-Wilk and One-Sample T-Tests for Hypothesis 1A: Delis-Kaplan Executive Function System

	Shapiro-Wilk Test		One- Sample T- Test				
Variable	Statistic	*p* value	M (SD)	df	t	*p* value	Effect Size (*d*)
Trail Making Test							
Number-letter switching	.94	.23	9.25 (2.99)	19	-1.12	.14	-.25
Verbal Fluency Test							
Letter fluency	.97	.69	8.90 (3.26)	19	-1.51	.07	-.34
Category Fluency	.94	.21	9.35 (2.72)	19	-1.07	.15	-.24
Design Fluency Test							
Filled Dots	.94	.21	9.10 (2.49)	19	-1.62	.06	-.36
Switching	.97	.69	9.65 (3.99)	19	-.39	.35	-.09

(table continues)

Table 5 cont.

	Shapiro-Wilk Test		One- Sample T- Test				
Variable	Statistic	*p* value	M (SD)	df	t	*p* value	Effect Size (*d*)
Total Correct	.97	.72	9.65 (3.62)	19	-.43	.34	-.10
Color-Word Interference Test							
Inhibition	.97	.81	9.65 (3.86)	19	-.41	.34	-.09
Inhibition/Switching	.95	.33	9.25 (3.23)	19	-1.04	.16	-.23
Tower Test							
Total Achievement	.96	.47	10.10 (1.89)	19	.24	.59	.05

Note. The normative mean for all tests is 10.

Table 6

Shapiro- Wilk and One-Sample T-Tests for Hypothesis 1B: Wisconsin Card Sorting Test

	Shapiro-Wilk Test		One- Sample T- Test				
Variable	Statistic	*p* value	M (SD)	df	t	*p* value	Effect Size (*d*)
Conceptual Level Responses	.95	.44	53.15 (10.33)	19	1.36	.91	.30
Perseverative Responses	.95	.42	54.40 (10.81)	19	1.82	.96	.41

Note. The normative mean for both tests is 50.

Table 7

Shapiro- Wilk and Binomial Tests for Hypothesis 1C: Letter-Number Sequencing

	Shapiro-Wilk Test		Binomial Test				
Variable	Statistic	*p* value	Median (Range)	Observed Proportion Scores ≤ 10	Observed Proportion Scores > 10	*p* value	Effect Size (*g*)
Letter-Number Sequencing	.91	.07	10.00 (1-18)	.55 (11)	.45 (9)	.41	.05

Note. The test proportion was set at .50. The cut point was the normative mean of 10.

Table 8

Shapiro- Wilk and One-Sample T-Tests for Hypothesis 1C: Working Memory Index and Associated Subtests

	Shapiro-Wilk Test		One- Sample T- Test				
Variable	Statistic	*p* value	M (SD)	df	t	*p* value	Effect Size (*d*)
Working Memory Index	.97	.65	100.00 (20.54)	19	.00	.50	.00
Digit Span	.97	.79	10.10 (2.90)	19	.15	.56	.03
Letter-Number Sequencing	.91	.07	10.10 (4.84)	19	.09	.54	.02

Note. Subtests are from Wechsler Intelligence Scale for Children - Fourth Edition. The normative mean is 100 for Working Memory Index and 10 for the Digit Span and Letter-Number Sequencing tests.

Table 9

Shapiro- Wilk and Binomial Tests for Hypothesis 2A: BRIEF Parent Form

	Shapiro-Wilk Test		Binomial Test				
Variable	Statistic	*p* value	Median (Range)	Observed Proportion Scores ≤ 10	Observed Proportion Scores > 10	*p* value	Effect Size (*g*)
Shift	.91	.07	54.50 (39-92)	.25 (5)	.75 (15)	.02	.25
Emotional Control	.91	.06	59.50 (43-73)	.30 (6)	.70 (14)	.06	.20

Note. The test proportion was set at .50. The cut point was the normative mean of 50.

Table 10

Shapiro- Wilk and One-Sample T-Tests for Hypothesis 2A: BRIEF Parent Form

	Shapiro-Wilk Test		One- Sample T- Test				
Variable	Statistic	*p* value	M (SD)	df	t	*p* value	Effect Size (*d*)
Inhibit	.96	.49	57.15 (9.90)	19	3.23	< .01	.72
Behavioral Regulation Index	.96	.52	58.70 (9.72)	19	4.00	< .01	.89
Initiate	.97	.71	63.10 (10.01)	19	5.85	< .01	1.31
Working Memory	.95	.43	61.15 (12.42)	19	4.02	< .01	.90
Plan/Organize	.97	.75	60.15 (10.37)	19	4.38	< .01	.98
Organization of Materials	.98	.92	52.75 (8.71)	19	1.41	.09	.32
Monitor	.98	.92	58.95 (9.74)	19	4.11	< .01	.92
Metacognition Index	.98	.89	60.85 (10.12)	19	4.79	< .01	1.07
Global Executive Composite	.97	.80	60.75 (10.15)	19	4.74	< .01	1.06

Table 11

Shapiro- Wilk and Binomial Tests for Hypothesis 2B: BRIEF Teacher Form (n = 14)

	Shapiro-Wilk Test		Binomial Test				
Variable	Statistic	*p* value	Median (Range)	Observed Proportion Scores ≤ 10	Observed Proportion Scores > 10	*p* value	Effect Size (*g*)
Inhibit	.80	< .01	52.00 (45-89)	.43 (6)	.57 (8)	.40	.07
Shift	.83	< .01	48.00 (44-73)	.57 (8)	.43 (6)	.60	-.07
Emotional Control	.88	.03	49.00 (45-64)	.57 (8)	.43 (6)	.60	.07
Behavioral Regulation Index	.88	.03	50.50 (44-77)	.50 (7)	.50 (7)	.50	.00
Initiate	.90	.06	52.50 (42-93)	.43 (6)	.57 (8)	.40	.07
Plan/Organize	.88	.02	55.00 (43-84)	.43 (6)	.57 (8)	.40	.07
Organization of Materials	.87	.02	55.00 (44-84)	.36 (5)	.64 (9)	.21	.14

(table continues)

Table 11 cont.

Variable	Shapiro-Wilk Test		Binomial Test				
	Statistic	*p* value	Median (Range)	Observed Proportion		*p* value	Effect Size (*g*)
				Scores ≤ 10	Scores > 10		
Monitor	.92	.15	56.50 (42-84)	.36 (5)	.64 (9)	.21	.14
Metacognition Index	.90	.06	56.00 (42-79)	.43 (6)	.57 (8)	.40	.07
Global Executive Composite	.90	.05	53.50 (43-81)	.43 (6)	.57 (8)	.40	.07

Note. The test proportion was set at .50. The cut point was the normative mean of 50.

Table 12

Shapiro- Wilk and One-Sample T-Tests for Hypothesis 2B: BRIEF Teacher Form (n = 14)

	Shapiro-Wilk Test		One- Sample T- Test				
Variable	Statistic	*p* value	M (SD)	df	t	*p* value	Effect Size (*d*)
Working Memory	.94	.34	58.64 (12.16)	13	2.66	.01	.71

Note. The normative mean for this test is 50. Higher scores indicate worse performance.

Table 13

Wilcoxon Signed Ranks Test for Hypothesis 2C: BRIEF Parent and Teacher Forms

Variable	Parent (n = 14) Median (Range)	Teacher (n = 14) Median (Range)	Statistic (z)	*p* value
Inhibit	57.00 (40-74)	52.00 (45-89)	-.42	.66
Shift	57.00 (39-92)	48.00 (44-73)	-.75	.77
Emotional Control	59.50 (43-73)	49.00 (45-64)	-2.11	.98
Behavioral Regulation Index	59.50 (42-76)	50.50 (44-77)	-1.82	.97
Initiate	63.00 (47-82)	52.50 (42-93)	-1.42	.92
Working Memory	62.50 (47-82)	55.50 (43-85)	-.31	.62
Plan/Organize	60.00 (42-80)	55.00 (43-84)	-.97	.84
Organization of Materials	54.00 (35-69)	55.00 (44-84)	-.04	.52

(table continues)

Table 13 cont.

Variable	Parent (n = 14) Median (Range)	Teacher (n = 14) Median (Range)	Statistic (z)	*p* value
Monitor	60.00 (43-81)	56.50 (42-84)	-.04	.52
Metacognition Index	62.00 (46-83)	56.00 (42-79)	-.79	.78
Global Executive Composite	60.50 (44-84)	53.50 (43-81)	-1.13	.87

Table 14

Shapiro- Wilk and Binomial Tests for Hypothesis 3A: BASC-2 Parent Rating Scale

	Shapiro-Wilk Test		Binomial Test				
Variable	Statistic	*p* value	Median (Range)	Observed Proportion		*p* value	Effect Size (*g*)
				Scores ≤ 50	Scores > 50		
Anxiety	.88	.02	50.50 (34-98)	.50 (10)	.50 (10)	.50	.00

Note. The test proportion was set at .50. The cut point was the mean of 50.

Table 15

Shapiro- Wilk and One-Sample T-Tests for Hypothesis 3A: BASC-2 Parent Rating Scale

	Shapiro-Wilk Test		One- Sample T- Test				
Variable	Statistic	*p* value	M (SD)	df	t	*p* value	Effect Size (*d*)
Hyperactivity	.96	.58	52.40 (9.99)	19	1.07	.15	.24
Depression	.98	.89	56.90 (9.75)	19	3.17	< .01	.71
Attention Problems	.97	.70	54.40 (11.53)	19	1.71	.05	.38

Note. The normative mean for the tests is 50. Higher scores indicate worse performance.

Table 16

Shapiro- Wilk and Binomial Tests for Hypothesis 3B: BASC-2 Teacher Rating Scale (n = 14)

	Shapiro-Wilk Test		Binomial Test				
Variable	Statistic	*p* value	Median (Range)	Observed Proportion Scores ≤ 50	Observed Proportion Scores > 50	*p* value	Effect Size (*g*)
Hyperactivity	.85	< .01	49.50 (42-66)	.50 (7)	.50 (7)	.50	.00
Anxiety	.89	.03	48.50 (38-72)	.64 (9)	.36 (5)	.21	-.14
Depression	.89	.04	50.50 (42-74)	.50 (7)	.50 (7)	.50	.00

Note. The test proportion was set at .50. The cut point was the mean of 50.

Table 17

Shapiro- Wilk and One-Sample T-Tests for Hypothesis 3B: BASC-2 Teacher Rating Scale (n = 14)

	Shapiro-Wilk Test		One- Sample T- Test				
Variable	Statistic	*p* value	M (SD)	df	t	*p* value	Effect Size (*d*)
Attention Problems	.96	.55	51.50 (10.64)	13	.53	.30	.14

Note: The normative mean for this test is 50. Higher scores indicate worse performance.

Table 18

Wilcoxon Signed Ranks Test for Hypothesis 3C: BASC-2 Parent and Teacher Rating Scales

Variable	Parent (n = 14) Median (Range)	Teacher (n = 14) Median (Range)	Statistic (z)	*p* value
Hyperactivity	49.50 (38-72)	49.50 (42-66)	-.69	.76
Anxiety	50.50 (41-98)	48.50 (38-72)	-1.71	.96
Depression	55.50 (37-74)	50.50 (42-74)	-1.29	.90
Attention Problems	57.00 (37-78)	51.00 (37-72)	-.94	.83

Table 19

Descriptive Statistics for Hypothesis 4A: Right Cerebellar Hemisphere Tumors and Language-Basted Tests

Variable	Tumor in Right Cerebellar Hemisphere			
	Yes (n = 6)		No (n = 14)	
	M (SD)	Median (Range)	M (SD)	Median (Range)
Verbal Fluency Test				
Letter Fluency	9.83 (3.87)	8.50 (6-16)	8.50 (3.03)	8.50 (2-13)
Category Fluency	9.33 (1.97)	9.00 (7-12)	9.36 (3.05)	9.00 (4-14)
Category Switching	9.00 (4.10)	7.50 (5-14)	9.64 (3.34)	9.00 (5-15)
Color-Word Interference Test				
Inhibition/Switching	9.33 (4.55)	10.50 (1-14)	9.21 (2.69)	9.50 (4-13)
Working Memory Index	104.50(15.23)	103.00(83-129)	98.07 (22.67)	98.00 (62-138)
Digit Span	9.83 (3.19)	10.50 (4-13)	10.21 (2.89)	10.50 (6-15)
Letter-Number Sequencing	12.00 (2.61)	11.50 (10-17)	9.29 (5.41)	9.50 (1-18)

Table 20

Descriptive Statistics for Hypothesis 4B: Left Cerebellar Hemisphere Tumors and Nonverbal Tests

Variable	Tumor in Left Cerebellar Hemisphere			
	Yes (n = 12)		No (n = 8)	
	M (SD)	Median (Range)	M (SD)	Median (Range)
Trail Making Test				
Letter-Number Switching	9.08 (3.40)	9.00 (2-14)	9.50 (2.45)	10.00 (5-12)
Design Fluency Test				
Filled Dots	9.67 (2.74)	9.00 (6-16)	8.25 (1.91)	8.50 (5-11)
Empty Dots	10.25 (2.99)	11.00 (5-14)	8.75 (2.92)	8.00 (5-14)
Switching	10.83 (2.86)	11.50 (4-14)	7.88 (4.94)	6.50 (2-17)
Total Correct Composite	10.58 (3.26)	11.50 (5-16)	8.25 (3.88)	8.00 (3-15)

(table continues)

Table 20 (cont.)

Variable	Tumor in Left Cerebellar Hemisphere			
	Yes (n = 12)		No (n = 8)	
	M (SD)	Median (Range)	M (SD)	Median (Range)
Tower Test				
Total Achievement	10.42 (1.08)	10.50 (9-12)	9.63 (2.72)	9.00 (6-13)
Wisconsin Card Sorting Test				
Conceptual Level Responses	54.83 (9.15)	54.50 (39-73)	50.63 (12.07)	54.00 (30-62)
Perseverative Responses	55.83 (10.79)	55.00 (39-73)	52.25 (11.20)	52.00 (38-73)

Table 21

Descriptive Statistics for Hypothesis 4C: Vermis Tumors and Psychological Functioning

Variable	Tumor in Vermis			
	Yes (n = 12)		No (n = 8)	
	M (SD)	Median (Range)	M (SD)	Median (Range)
BASC-2 Parent Rating Scale				
Hyperactivity	53.08 (11.10)	52.50 (38-72)	51.38 (8.68)	53.00 (39-64)
Aggression	54.00 (11.69)	48.50 (42-79)	49.88 (13.33)	48.50 (37-78)
Conduct Problems	55.25 (15.07)	54.50 (39-86)	49.63 (9.90)	47.00 (37-66)
Externalizing Problems	54.67 (12.72)	53.00 (40-77)	50.25 (10.95)	49.50 (36-69)
Anxiety	52.42 (17.61)	45.50 (34-98)	57.75 (13.75)	55.00 (43-85)
Depression	58.83 (10.40)	57.50 (43-75)	54.00 (8.49)	54.50 (37-67)

(table continues)

Table 21 (cont.)

Variable	Tumor in Vermis			
	Yes (n = 12)		No (n = 8)	
	M (SD)	Median (Range)	M (SD)	Median (Range)
BASC-2 Parent Rating Scale				
Somatization	56.42 (15.86)	50.50 (36-84)	51.63 (11.39)	49.50 (41-77)
Internalizing Problems	57.17 (16.20)	51.50 (39-91)	55.50 (10.01)	55.00 (41-71)
Atypicality	54.25 (9.83)	51.00 (41-76)	52.63 (9.09)	50.50 (41-65)
Withdrawal	56.08 (11.26)	59.00 (35-77)	62.13 (9.98)	64.00 (46-77)
Attention Problems	52.33 (10.75)	56.50 (35-67)	57.50 (12.69)	57.00 (37-78)
Behavior Symptoms Index	56.17 (10.84)	57.50 (37-72)	56.00 (10.07)	55.50 (38-68)

(table continues)

Table 21 (cont.)

Variable	Tumor in Vermis			
	Yes (n = 8)		No (n = 6)	
	M (SD)	Median (Range)	M (SD)	Median (Range)
BASC-2 Teacher Rating Scale				
Hyperactivity	50.63 (8.81)	50.50 (42-66)	49.17 (7.44)	48.00 (42-58)
Aggression	51.50 (9.10)	48.50 (43-67)	48.67 (6.56)	47.00 (43-61)
Conduct Problems	50.38 (8.28)	46.50 (43-64)	48.83 (7.47)	47.00 (42-62)
Externalizing Problems	51.00 (8.82)	48.00 (43-64)	48.83 (6.37)	46.50 (43-61)
Anxiety	50.88 (9.66)	50.50 (39-72)	44.83 (6.05)	45.00 (38-53)
Depression	55.38 (11.26)	55.50 (42-74)	47.67 (5.82)	46.50 (42-56)
Somatization	56.38 (10.68)	59.00(43-68)	47.50 (4.55)	47.00 (43-55)

(table continues)

Table 21 (cont.)

Variable	Tumor in Vermis			
	Yes (n = 8)		No (n = 6)	
	M (SD)	Median (Range)	M (SD)	Median (Range)
BASC-2 Teacher Rating Scale				
Internalizing Problems	55.25 (11.51)	55.00 (41-76)	45.83 (4.31)	46.00 (40-51)
Attention Problems	52.75 (11.41)	52.50 (37-72)	49.83 (10.30)	47.00 (39-66)
Learning Problems	49.25 (10.20)	48.00 (40-71)	47.50 (6.66)	44.50 (42-59)
School Problems	51.13 (11.31)	51.50 (37-73)	48.33 (8.85)	45.00 (41-63)
Atypicality	51.63 (6.74)	51.00 (44-63)	46.50 (3.62)	45.00 (43-51)
Withdrawal	54.75 (14.29)	50.50 (38-74)	46.67 (7.12)	45.50 (38-55)
Behavioral Symptoms Index	53.38 (8.35)	54.50 (40-66)	47.83 (6.31)	47.50 (40-57)

Note. Six participants did not have teacher questionnaires available.

Table 22

Descriptive Statistics for Hypothesis 4D: Posterior Cerebellar Tumors and Test Performance

Variable	Tumor in Cerebellar Posterior Lobe			
	Yes (n = 18)		No (n = 2)	
	M (SD)	Median (Range)	M (SD)	Median (Range)
Trail Making Test				
Number-letter switching	9.44 (3.09)	10.00 (2-14)	7.50 (.71)	7.50 (7-8)
Verbal Fluency Test				
Letter Fluency	9.11 (3.36)	9.00 (2-16)	17.00 (1.41)	7.00 (6-8)
Category Fluency	9.50 (2.83)	9.50 (4-14)	8.00 (.00)	8.00 (8-8)
Category Switching	9.39 (3.42)	8.50 (5-15)	10.00 (5.66)	10.00 (6-14)

(table continues)

Table 22 cont.

Variable	Tumor in Cerebellar Posterior Lobe			
	Yes (n = 18)		No (n = 2)	
	M (SD)	Median (Range)	M (SD)	Median (Range)
Design Fluency Test				
Filled Dots	9.17 (2.61)	9.00 (5-16)	8.50 (.71)	8.50 (8-9)
Empty Dots	9.94 (2.98)	10.00 (5-14)	7.00 (1.41)	7.00 (6-8)
Switching	9.94 (3.98)	10.50 (2-17)	7.00 (4.24)	7.00 (4-10)
Total Correct	9.94 (3.64)	10.50 (3-16)	7.00 (2.83)	7.00 (5-9)
Color-Word Interference Test				
Inhibition	9.94 (3.90)	10.00 (1-19)	7.00 (2.83)	7.00 (5-9)
Inhibition/Switching	9.28 (3.39)	10.00 (1-14)	9.00 (1.41)	9.00 (8-10)

(table continues)

Table 22 cont.

Variable	Tumor in Cerebellar Posterior Lobe			
	Yes (n = 18)		No (n = 2)	
	M (SD)	Median (Range)	M (SD)	Median (Range)
Twenty Questions Test				
Initial Abstraction	9.22 (2.71)	8.50 (6-16)	9.00 (1.41)	9.00 (8-10)
Total Weighted Achievement	10.11 (2.85)	10.11 (2-13)	10.50 (2.12)	10.50 (9-12)
Tower Test				
Total Achievement	10.17 (1.98)	10.50 (6-13)	9.50 (.71)	9.00 (8-10)
Wisconsin Card Sorting Test				
Conceptual Level Responses*	53.39 (10.87)	55.50 (30-73)	51.00 (2.83)	51.00 (49-53)
Perseverative Responses*	54.44 (11.42)	55.00 (38-73)	54.00 (1.41)	54.00 (53-55)

(table continues)

Table 22 cont.

Variable	Tumor in Cerebellar Posterior Lobe			
	Yes (n = 18)		No (n = 2)	
	M (SD)	Median (Range)	M (SD)	Median (Range)
Wechsler Intelligence Scale for Children - Fourth Edition				
Working Memory Index**	101.83(20.19)	101.50(62-138)	83.50 (21.92)	83.50 (68-99)
Digit Span**	10.22 (3.02)	11.00 (4-15)	9.00 (1.41)	9.00 (8-10)
Letter-Number Sequencing**	10.61 (4.59)	10.50 (1-18)	5.50 (6.36)	5.50 (1-10)

Note. Subtests are by scaled scores (*M* = 10, SD = 3), unless otherwise noted. *T-scores (*M* = 50, SD = 10). **Standard scores (*M* = 100, SD = 15).

Table 23

Shapiro- Wilk and Binomial Tests for Exploratory Analyses 1: BASC-2 Parent Rating Scale

Variable	Shapiro-Wilk Test		Binomial Test				
	Statistic	*p* value	Median (Range)	Observed Proportion Scores ≤ 50	Observed Proportion Scores > 50	*p* value	Effect Size (*g*)
Aggression	.88	.02	48.50 (37-79)	.65 (13)	.35 (7)	.26	-.15
Conduct Problems	.92	.10	49.50 (37-86)	.50 (10)	.50 (10)	>.99	.00
Somatization	.89	.02	50.50 (36-84)	.50 (10)	.50 (10)	>.99	.00
Internalizing Problems	.92	.10	51.50 (39-91)	.50 (10)	.50 (10)	>.99	.00
Atypicality	.93	.16	51.00 (41-76)	.45 (9)	.55 (10)	.82	.05

Note. The test proportion was set at .50. The cut point was the normative mean of 50.

Table 24

Shapiro- Wilk and One-Sample T-Tests for Exploratory Analyses 1: BASC-2 Parent Rating Scale

	Shapiro-Wilk Test		One- Sample T- Test				
Variable	Statistic	*p* value	M (SD)	df	t	*p* value	Effect Size (*d*)
Clinical Scales							
Conduct Problems	.92	.10	53.00 (13.25)	19	1.01	.32	.23
Externalizing Problems	.94	.22	52.90 (11.95)	19	1.09	.29	.24
Internalizing Problems	.92	.10	56.50 (13.77)	19	2.11	.05	.47
Atypicality	.93	.16	53.60 (9.33)	19	1.73	.10	.39
Withdrawal	.98	.95	58.50 (10.92)	19	3.48	< .01	.78
Behavioral Symptoms Index	.95	.29	56.10 (10.26)	19	2.66	.02	.59

(table continues)

Table 24 cont.

Variable	Shapiro-Wilk Test		One- Sample T- Test				
	Statistic	*p* value	M (SD)	df	t	*p* value	Effect Size (*d*)
Adaptive Scales							
Adaptability	.97	.74	46.25 (7.84)	19	-2.14	.05	-.48
Social Skills	.94	.26	42.90 (9.06)	19	-3.50	< .01	-.78
Leadership	.97	.79	45.85 (9.05)	19	-2.05	.05	-.46
Activities of Daily Living	.98	.90	44.85 (9.00)	19	-2.56	.02	-.57
Functional Communication	.98	.85	43.80 (10.56)	19	-2.63	.02	-.59
Adaptive Skills	.96	.56	43.80 (7.80)	19	-3.56	< .01	-.80

Note. The normative mean for the tests is 50. Higher scores indicate worse performance.

Table 25

Results of Shapiro- Wilk and Binomial Test for Exploratory Analyses 2: BASC-2 Teacher Rating Scale (n = 14)

	Shapiro-Wilk Test		Binomial Test				
Variable	Statistic	*p* value	Median (Range)	Observed Proportion Scores ≤ 50	Observed Proportion Scores > 50	*p* value	Effect Size (*g*)
Aggression	.81	.02	48.00 (43-67)	.71 (10)	.29 (4)	.18	-.21
Conduct Problems	.89	.03	46.50 (42-64)	.64 (9)	.36 (5)	.42	-.14
Externalizing Problems	.83	< .01	46.50 (43-64)	.71 (10)	.29 (4)	.18	-.21
Somatization	.82	< .01	48.50 (43-68)	.57 (8)	.43 (6)	.79	-.07
Internalizing Problems	.91	.09	50.00 (40-76)	.57 (8)	.43 (6)	.79	-.07
Learning Problems	.85	< .01	45.50 (40-71)	.64 (9)	.36 (5)	.42	-.14
Atypicality	.85	< .01	49.00 (43-63)	.57 (8)	.43 (6)	.79	-.07
Withdrawal	.91	.10	49.00 (38-74)	.57 (8)	.43 (6)	.79	-.07

Note. The test proportion was set at .50. The cut point was the normative mean of 50.

Table 26

Shapiro- Wilk and One-Sample T-Test for Exploratory Analyses 2: BASC-2 Teacher Rating Scale (n = 14)

	Shapiro-Wilk Test		One- Sample T- Test			
Variable	Statistic	*p* value	M (SD)	t (13)	*p* value	Effect Size (*d*)
School Problems	.94	.29	49.93 (10.05)	-.03	.98	.00
Behavioral Symptoms Index	.96	.55	51.00 (7.81)	.48	.64	.13
Adaptability	.94	.24	51.14 (9.75)	.44	.67	.12
Social Skills	.98	.89	50.93 (12.80)	.27	.79	.07
Leadership	.96	.55	50.21 (12.77)	.06	.95	.02
Study Skills	.94	.29	49.21 (11.48)	-.26	.80	-.07
Functional Communication	.94	.32	49.93 (11.26)	-.02	.98	.00
Adaptive Skills	.96	.59	50.29 (12.44)	.09	.93	.02

Note. The normative mean for these tests is 50. Higher scores indicate worse performance.

APPENDIX A
Patient Medical Chart Review Form

For Office Use Only   Patient ID: _______________   Date of Evaluation: _________

MEDICAL CHART REVIEW FORM

Patient's Name: _________________________________ MRN: __________________

Date of Birth: ____________________________ Gender: Male ______ Female _____

Date of Evaluation: ______________________ Age at Evaluation: ____________

INCLUSION CRITERIA MET

_____ Radiographically diagnosed cerebellar region brain tumor
_____ Histopathologically diagnosed pilocytic astrocytoma
_____ Surgical treatment only
_____ Current age: eight and sixteen years
_____ At least one-year post surgery
_____ No history of tumor recurrence
_____ No significant neurological, developmental, or psychiatric disorders that would prevent the completion of the neuropsychological test battery
_____ Completion of signed informed consent by parent/guardian or 18yo participant
_____ Subject's assented to participate in the protocol if minor
_____ Proficiency in English

Date of Diagnosis: ______________________ Age at Diagnosis: _______________

Type of tumor: _____ Pilocytic Astrocytoma   _____ Other (excluded from study)

_____ Cystic   _____ Solid

Preoperative conditions: _____ Headache _____ Nausea _____ Vomiting

_____ Gait ataxia _____ Arm ataxia _____ Weakness

_____ Diplopia _____ Seizures _____ Macrocephaly

_____ Other: _____________________________________

Brain imaging: _____ CT Scan _____ MRI _____ Other: ____________

Date(s) of brain imaging: ____

Scans available for review: _____ Yes _____ No

Treated with chemotherapy: _____ No _____ Yes (if yes, excluded from study)

Treated with radiation: _____ No _____ Yes (if yes, excluded from study)

Date of Surgery: ____________________ Age at Surgery: _______________

Surgical procedures:
_____ Suboccipital craniotomy
_____ Suboccipital craniectomy
_____ Posterior fossa craniotomy
_____ C1 laminectomy
_____ Other: ____________________

Resection:
_____ Gross total resection
_____ Subtotal resection
_____ Not Available

Location of tumor:
_____ Vermis- Anterior
_____ Vermis- Posterior
_____ Right cerebellar hemisphere - Anterior
_____ Right cerebellar hemisphere- Posterior
_____ Left cerebellar hemisphere- Anterior
_____ Left cerebellar hemisphere- Posterior

Perioperative/Postoperative Procedure and Complications:

_____ Shunt Insertion
    _____ Right Frontal
    _____ Left Frontal
_____ Ventriculostomy
_____ Infection
_____ Brain swelling

APPENDIX B
PATIENT HISTORY FORM

For Office Use Only   Patient ID: ______________   Date of Evaluation: _________

HISTORY FORM

Please complete the following information as completely as you can. This information will be helpful in gaining a better understanding of your child.

Child's Name: ____

Age: ______ Date of Birth: ____________ Racial/Ethnicity: __________________________

Sex: _____ Male _____ Female   Handedness: _____ Right _____ Left

Languages spoken: ___________________________ Home Phone: ______________________

Address: ____

PARENT HISTORY

Mother's Name: ____ Age: __________

Occupation (please provide specific job title): _______________________________________

Highest grade completed: ______________ Degree obtained: __________________________

Father's Name: ____ Age: __________

Occupation (please provide specific job title): _______________________________________

Highest grade completed: ______________ Degree obtained: __________________________

PREGNANCY AND DELIVERY

Where was your child born? ____

Was your child born: Early (If so, how early?) __________ On time ______ Late ______

How long was the labor? ___________ Was the labor induced? No _____ Yes _____

Delivery: Normal _____ Breech _____ C-section _____

Forceps used? No _____ Yes _____

At birth, was your child considered? Normal _____ Abnormal _____

If abnormal, explain: ____

Were there any complications with the pregnancy or delivery? No _____ Yes _____

If yes, explain: ____

DEVELOPMENTAL HISTORY

Please describe your child's abilities compared to other children his/her age:

	Below Average	Average	Above Average
Motor development	_____________	_____________	_____________
Current physical abilities	_____________	_____________	_____________
Speech/language development	_____________	_____________	_____________
Current speech/language	_____________	_____________	_____________
Comprehension and understanding	_____________	_____________	_____________

Have there been any concerns about your child's development? ________________________

____

Has your child ever had physical/occupational therapy? No _____ Yes _____ When? ______

Has your child ever had speech therapy? No _____ Yes _____ When? _________________

Learning Problems? No _____ Yes _____ Briefly explain: _________________________

Behavior/Emotional Problems? No _____ Yes _____ If yes, when? ____________________

SCHOOL HISTORY

Current grade: _____________ Name of School: ______________________________

Did your child attend an Early Childhood Intervention Program (ECI) or Preschool Program for Children with Disabilities (PPCD)? No _____ Yes _____

Has your child ever been retained? No _____ Yes _____ If yes, which grade? __________

Has your child ever had psychological or academic testing? No _____ Yes _____

If yes, by whom, when, and what were the results? _________________________________

____

Has your child ever received special education services, i.e., ever had an ARD meeting? Have an Individualized Education Program (IEP)? No _____ Yes _____

If yes, classification? _____ Other Health Impairment _____ Learning Disability

_____ Speech/Language Impairment _____ Other: __________

Type of special education services
_____ Self-contained class
_____ Pull out (resource room, content mastery)

What subjects? ____

Describe briefly any academic school problems ___________________________________

____

Academic performance: Above average ______ Average ______ Below average _____

MEDICAL HISTORY

Medical problems:

Diagnosis/Disease (Present and Past)	Date	Treatment
______________________	________	______________
______________________	________	______________
______________________	________	______________

Medications (past and present): ____ Check if none

Name	Reason	Date
___________________	________________	________
___________________	________________	________
___________________	________________	________

Does your child have vision problems? No _____ Yes _____
If yes, does your child wear corrective lenses? No _____ Yes _____

Does your child have hearing problems? No _____ Yes _____
If yes, does your child use hearing aids? No _____ Yes _____

If there is anything else that you feel we need to know about your child, please feel free to explain here:

____

____

____

Form completed by: ____

Relationship to child: ________________________

Date:______________________

Thank you for your participation in this research study!

APPENDIX C
Consent Form

The University of Texas Southwestern Medical Center at Dallas
Children's Medical Center

CONSENT TO PARTICIPATE IN RESEARCH

Title of Research:	Executive Functioning in Child Survivors of Pediatric Cerebellar Astrocytoma	
Funding Agency/Sponsor:	UT Southwestern Medical Center	
Investigators:		
	Telephone No. (regular office hours)	Telephone No. (other times)
Pete Stavinoha, Ph.D.	214-456-8985	214-456-6040
Christine Castillo, Ph.D.	214-456-5872	214-456-6040
Lynn Gargan, Ph.D.	214-456-6150	214-456-6040
Kristy Hagar, Ph.D.	214-456-8198	214-456-6040
Roger Perez	214-456-8985	214-456-6040
Sara Schnoebelen, Ph.D.	214-456-7235	214-456-6040
Dale Swift, M.D.	214-456-6660	972-601-9685 (Pager)

Note: If you are a parent or guardian of a minor and have been asked to read and sign this form, the "you" in this document refers to the minor.

Instructions:
Please read this consent form carefully and take your time making a decision about whether to participate. As the researchers discuss this consent form with you, please ask him/her to explain any words or information that you do not clearly understand. The purpose of the study, risks, inconveniences, discomforts, and other important information about the study are listed below. If you decide to participate, you will be given a copy of this form to keep.

Why is this study being done?
The purpose of this study is to investigate executive functioning in child survivors of cerebellar astrocytomas.

Why is this considered research?
This is a research study because the researchers are investigating the effects of cerebellar pilocytic astrocytomas on executive functioning in child survivors.

The following definitions may help you understand this study:

- Standard medical care means the regular care you would receive from your personal doctor if you choose not to participate in this research.
- Researchers means the study doctor and research personnel at the University of Texas Southwestern Medical Center at Dallas and its affiliated hospitals.

Why am I being asked to take part in this research study?
You are being asked to take part in this study because you have undergone surgical resection of a cerebellar pilocytic astrocytoma.

How many people will take part in this study?
About 75 people will take part in this study at Children's Medical Center.

What is involved in the study?
If you agree to be in this study, you will be asked to sign this consent form and will have the following tests.

Screening Procedures
To help decide if you qualify to be in this study, the researchers may ask you questions about your background history, including presence of any neurological, developmental, or psychiatric disorders. The researchers may also ask you questions about your health, including diagnosis, medical treatments, and any surgical procedures you have had.

Evaluations during the Research

A series of neuropsychological tests will be administered to your child. These pen and paper tests will take approximately three hours to complete. The tests will evaluate intelligence and multiple components of executive functions, including concept formation, fluency, inhibition, mental flexibility, planning, and working memory.

Parents will complete three questionnaires. One questionnaire will be used to collect background history, such as the child's developmental and school history, family medical, psychiatric, and educational history, and relevant demographic information. The other two questionnaires will assess the child's overt executive function behaviors and emotional, behavioral, and social functioning.

Teachers will be asked to complete two questionnaires that assess the child's overt executive function behaviors and emotional, behavioral, and social functioning.

If a participant has been administered a measure of intelligence within the past year, then those results will be obtained and used. Participants who are found to have significant cognitive problems will be provided with contact information for psychologists who can provide a more comprehensive evaluation. Because the testing done in this study is not for medical or academic purposes, the research test data will not be sent to you, your regular doctor, or your school. However, parents will be provided with a summary letter describing their child's performance.

The participant's medical charts will be reviewed to obtain data concerning medical information required for standard of care treatment for pediatric brain tumor patients. Information will include preoperative conditions, tumor type, brain imaging, surgical procedures, treatment modalities, and medical complications (i.e., hydrocephalus, shunt insertions, infections).

Participation in the study will not alter the medical treatment you receive.

How long can I expect to be in this study?
The evaluation of the child will take approximately 3 hours to complete. Questionnaires will take parents approximately 1.5 hours to complete and teachers approximately 30 minutes to complete. You can choose to stop participating for any reason at any time.

What are the risks of the study?
Neuropsychological and psychological tests are noninvasive and carry no inherent risks. However, your child may experience mild frustration or nervousness due to cognitively challenging tasks.

Loss of Confidentiality
Any time information is collected; there is a potential risk for loss of confidentiality. Every effort will be made to keep your information confidential; however, this cannot be guaranteed.

You should understand that the investigator is not prevented from reporting information to authorities in order to prevent serious harm to you or to others. If the investigator suspects child, elder or disabled persons abuse, they will report such concerns to proper authorities as required by law.

How will risks be minimized or prevented?
If at any point during the evaluation you experience discomfort as a result of the testing, you may refuse to answer any of the questions, take a break, or stop your participation in this study at any time.

What will my responsibilities be during the study?
While you are part of this study, the researchers will follow you closely to determine whether there are problems that need medical care. It is your responsibility to do the following:

- Ask questions about anything you do not understand.
- Keep your appointments.
- Follow the researchers' instructions.
- Let the researchers know if your telephone number or address changes.

If I agree to take part in this research study, will I be told of any new risks that may be found during the course of the study?
Yes. You will be told if any new information becomes available during the study that could cause you to change your mind about continuing to participate or that is important to your health or safety.

What should I do if I think I am having problems?
If you have unusual symptoms, pain, or any other problems while you are in the study, you should report them to the researchers right away. Telephone numbers where they can be reached are listed on the first page of this consent form.

If you have a sudden, serious problem, like difficulty breathing or severe pain, go to the nearest hospital emergency room, or call 911 (or the correct emergency telephone number in your area). Tell emergency personnel about any medications you are taking, including any medications you are taking for this study.

What are the possible benefits of this study?
If you agree to take part in this study, there may not be direct benefits to you. The researchers cannot guarantee that you will benefit from participation in this research. You will receive a neuropsychological evaluation of executive function at no cost to you. This can help you learn about your child's own specific strengths and weaknesses in executive function.

We hope the information learned from this study will benefit others with cerebellar pilocytic astrocytomas in the future. Information gained from this research could lead to advanced knowledge of executive functions in children treated fro cerebellar pilocytic astrocytomas and advanced knowledge of the impact of executive functions on these patient's home and school activities. Moreover, the knowledge obtained can be used for identification of a special-needs population as well as for academic and cognitive intervention.

What options are available if I decide not to take part in this research study?
You and your child have the option not to participate in this research. This decision will not affect the care your child receives at Children's Medical Center of Dallas.

Will I be paid if I take part in this research study?

No. You will not be paid to take part in this research study. There are no funds available to pay for parking expenses, transportation to and from the research center, lost time away from work and other activities, lost wages, or childcare expenses. However, you will receive a letter summarizing your child's performance on the neuropsychological measures.

Will my insurance provider or I be charged for the costs of any part of this research study?
No. Neither you, nor your insurance provider, will be charged for anything done only for this research study (i.e., the Screening Procedures, Experimental Procedures, or Monitoring/Follow-up Procedures described above).

However, the standard medical care for your condition (care you would have received whether or not you were in this study) is your responsibility (or the responsibility of your insurance provider or governmental program). You will be charged, in the standard manner, for any procedures performed for your standard medical care.

What will happen if I am harmed as a result of taking part in this study?
It is important that you report any illness or injury to the research team listed at the top of this form immediately.

Compensation for an injury resulting from your participation in this research is not available from the University of Texas Southwestern Medical Center at Dallas or Children's Medical Center.

Can I stop taking part in this research study?
Yes. If you decide to participate and later change your mind, you are free to stop taking part in the research study at any time.

If you decide to stop taking part in this research study, it will not affect your relationship with the UT Southwestern staff or doctors. Whether you participate or not will have no effect on your legal rights or the quality of your health care.

If you are a medical student, fellow, faculty, or staff at the Medical Center, your status will not be affected in any way.

Your doctor is a research investigator in this study. S/he is interested in both your medical care and the conduct of this research study. At any time, you may discuss your care with another doctor who is not part of this research study. You do not have to take part in any research study offered by your doctor.

If I agree to take part in this research study, can I be removed from the study without my consent?
Yes. The researchers may decide to take you off this study if:

- Your medical problem remains unchanged or becomes worse.

- The researchers believe that participation in the research is no longer safe for you.
- The researchers believe that other treatment may be more helpful.
- The sponsor or the FDA stops the research for the safety of the participants.
- The sponsor cancels the research.
- You are unable to keep appointments or to follow the researcher's instructions.

Will my information be kept confidential?
Information about you that is collected for this research study will remain confidential unless you give your permission to share it with others, or if we are required by law to release it. You should know that certain organizations that may look at and/or copy your medical records for research, quality assurance, and data analysis include:

- Peter L. Stavinoha, Ph.D.;
- Representatives of government agencies, like the U.S. Food and Drug Administration (FDA), involved in keeping research safe for people; and
- The UT Southwestern Institutional Review Board.

In addition to this consent form, you will be asked to sign an "Authorization for Use and Disclosure of Protected Health Information." This authorization will give more details about how your information will be used for this research study, and who may see and/or get copies of your information.

Are there procedures I should follow after stopping participation in this research?
No. There are no procedures that should be followed after terminating participation in the study.

Whom do I call if I have questions or problems?
For questions about the study, contact Peter L. Stavinoha, Ph.D. at 214-456-8985 during regular business hours and at 214-456-6040 after hours and on weekends and holidays.

For questions about your rights as a research participant, contact the UT Southwestern Institutional Review Board (IRB) Office at 214-648-3060.

SIGNATURES:

YOU WILL BE GIVEN A COPY OF THIS CONSENT FORM TO KEEP.

Your signature below certifies the following:

- You have read (or been read) the information provided above.
- You have received answers to all of your questions and have been told who to call if you have any more questions.
- You have freely decided to participate in this research.
- You understand that you are not giving up any of your legal rights.

____

Participant's Name (printed)

____ ________________

Participant's Signature Date

____

Legally Authorized Representative's Name (printed)

____ ________________

Legally Authorized Representative's Signature Date

____

Name of person obtaining consent (printed)

____ ________________

Signature of person obtaining consent Date

ASSENT OF A MINOR:

I have discussed this research study with my parent or legal guardian and the researchers, and I agree to participate.

__________________________________ ________________

Signature of participant (age 10 through 17) Date

INTERPRETER STATEMENT:

I have interpreted this consent form into a language understandable to the participant and the participant has agreed to participate as indicated by their signature above.

____
Name of Interpreter (printed)

____ ____________________
Signature of Interpreter Date

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VITAE

Roger Perez was born in Orange, California, on December 16, 1979. He is the son of Rogelio and Ana Maria Perez. He graduated from El Modena High School in Orange, California in 1998. In May 2002, he received Bachelor of Arts degrees in Psychology and Spanish from the University of San Diego. He entered the Clinical Psychology Graduate Program at the University of Texas Southwestern Medical Center at Dallas in August 2003. In August 2007, he married Deirdre Caroline Crampton of Vista, California. Following completion of his Ph.D., he will begin a Postdoctoral Fellowship in Pediatric Neuropsychology at Advanced Neurobehavioral Health of Southern California in San Diego, California.

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