Academic Achievement in Survivors of Pediatric Brain Tumors

Master’s Thesis

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By

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Abstract

PURPOSE: To evaluate the academic achievement of survivors of pediatric brain tumors relative to case-control classmates and determine the extent to which deficits are moderated by type of treatment, family socioeconomic status, parental education level, and quality of family environment. Survivors are known to be at risk of cognitive and academic impairments following treatment, however the degree of impairment varies and limited research examining the role of these factors and possible interactions between them exists.

METHODS: Brain tumor survivors, ages 5-18 and 1-5 years post treatment, were recruited from tumor registries at four pediatric hospitals in the US and Canada to participate in data collection in each child’s school and home. A case-control classmate matched for age, gender, and race was identified for each survivor. Measures included the Wide Range Achievement Test, parent demographic questionnaire, and Family Environment Scale. Medical data was obtained via chart review. Analyses include 164 pairs of brain tumor survivors and classmate controls.

RESULTS: Survivors demonstrated significantly lower achievement than controls in reading, spelling, and arithmetic, ($p = .01$). Deficits in academic achievement were found
among children treated with Neurosurgery only as well as for those who received chemotherapy and/or radiation. Results suggested that the discrepancy in academic achievement between survivors and controls across all three academic domains may be heightened when survivors reside in home environments characterized by less support or more conflict. Possible interactions between family characteristics and treatment intensity were examined but not found to be significant.

CONCLUSIONS: This study supports frequently noted concerns about the potential impact of treatment for pediatric cancer on survivors’ quality of life. We also find evidence that survivors treated with neurosurgery only also experience academic difficulties and could benefit from support services and collaboration between medical and school systems. Finally, aspects of family environment may impact survivors’ achievement, which offers potential for the development of targeted interventions.
Dedication

“Be a rainbow in someone else’s cloud.”

-Maya Angelou

To all my friends and family who have been steadfast rainbows in my clouds. Thank you.
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ACADEMIC ACHIEVEMENT IN SURVIVORS OF PEDIATRIC BRAIN TUMORS

Background

According to the National Cancer Institute, approximately 2,200 children are diagnosed with brain tumors annually in the United States and account for 17% of all cancer diagnoses in individuals under 18 years old (Jemal et al., 2009; Levy, 2005; Linet, Ries, Smith, Tarone, & Devesa, 1999). There are more than a hundred different types of brain tumors each classified by their histology, location, and pattern of cell growth (Levy, 2005; Packer, 2005). However, morbidity and mortality rates vary widely across tumor types.

Over the past 30 years, advances in diagnostic techniques (e.g., MRI technology enabling earlier detection) (Gurney, Wall, Jukich, & Davis, 1999; Packer, 2005) and more aggressive treatment protocols have led to a 20% decline in mortality for children with brain tumor. Overall survival rates for children with brain tumors now exceed 65% but vary by tumor type (National Cancer Institute, 2007). Some tumors, such as low grade astrocytomas, have survival rates that exceed 80%. They are typically treated with complete surgical resection and require no further treatment (Choucair et al., 1997; Kun, 1997; Levy, 2005; Linet et al., 1999; Packer, 2005). Other tumor types require adjuvant or multimodal therapy to eradicate or slow their growth when complete resection is not possible. For example, medulloblastoma, the most common form of malignant brain
tumor in children, is treated with surgery, radiation, and chemotherapy over a 12 to 18 month period (National Childhood Cancer Foundation, 2005). Currently, the five year survival rate for medulloblastoma is between 70% - 80% (Levy, 2005; Partap & Fisher, 2007). This reflects a dramatic increase over the 50% survival rate three decades ago (Jemal et al., 2009; Packer, 2005; Partap & Fisher, 2007).

Improvements in survival rates raise concerns about the functional outcomes and quality of life experienced by affected children. It has long been recognized that children who undergo treatment directed at the central nervous system (CNS), for brain tumors or other forms of cancer, experience deficits in intellectual and academic functioning (Barrera, Shaw, Speechley, Maunsell, & Pogany, 2005; Mostow, Byrne, Connelly, & Mulvihill, 1991; Reimers et al., 2003). Specifically, brain tumor survivors are more likely to: (a) receive services for learning disabilities (19% vs. 7%), (b) be enrolled in a special education program (20% vs. 8%), or (c) experience academic problems requiring extra tutoring or academic support services (46% vs. 23%), or (d) repeat a grade (21% vs. 9%) (Barrera et al., 2005; Lahteenmaki, Huostila, Hinkka, Salmi, 2002). Pediatric brain tumor survivors are significantly less likely to graduate from high school compared to survivors of non-CNS childhood cancers and healthy controls (Mitby et al., 2003). These deficits are of concern because they are often associated with diminished educational attainment, poor social adjustment, and lower overall quality of life that may persist into adulthood (Levin Newby, Brown, Pawletko, Gold, & Whitt, 2000; Mostow et al., 1991).

Impairment in academic achievement and progress may have long term implications for survivors’ functional outcomes (Barrera et al., 2005; Lahteenmaki et al., 2002). Mostow et al. (1991) reported that 15% of adult survivors of childhood brain and
CNS tumors have never been employed, and 37% report a health condition that has forced them to change jobs or stop working entirely. Without a high school diploma, an individual faces limited employment opportunities, higher unemployment rates, and diminished earning potential (Rumberger, 1987).

Neurocognitive impairment, some of which may be associated with the treatment the child received, has been reported to some degree in as many as 70% of pediatric brain tumors survivors, though rates vary (Mulhern, Merchant, Gajjar, Reddick, & Kun, 2004). Deficits include slower processing speed, impairments in short-term memory, and deficits in attention and executive functioning (Dennis et al., 1991; Meadows, Gordon, Massari, Littman, Fergusson, & Moss, 1981; Mulhern & Butler, 2004; Hancock, Fairclough, & Kun, 1992; Mulhern et al., 2004). These core cognitive skills may be crucial to the acquisition and retention of new information, underlie the development of new academic skills and school progress, and their impairment may explain some of the academic deficits survivors demonstrate (Mulhern et al., 2004).

In 2003, Reddick and colleagues proposed a developmental model to explain impairment in academic achievement and broader intellectual abilities among brain tumor survivors (Reddick et al., 2003). Starting with the impact of treatment, Reddick notes the well documented findings that radiation and some chemotherapeutic agents contribute to structural changes and damage to otherwise healthy brain tissue. The damage to normal appearing white matter (healthy brain tissue) is thought to compromise the integrity of the complex, distributed neural networks believed necessary for typical cognitive functioning. This damage may result in neurocognitive deficits, specifically impaired memory and attention skills, which may preclude children from acquiring new
information and skills at a rate commensurate with their peers. In time, children fall behind their classmates and demonstrate impaired academic achievement (Dennis, Hetherington, & Spiegler, 1998).

Inconsistent findings have been reported as to the academic domains that are affected for brain tumor survivors. Some studies suggest specific academic domains, such as arithmetic (Copeland et al., 1988; Ochs et al., 1991) or reading (Palmer, 2008) may be more negatively affected than other domains. Other studies do not report differences among affected domains (Mabbott et al., 2005; Reddick et al., 2003). While it remains unclear whether certain academic domains are more or less affected than others, consistent across studies is the presence of impaired academic achievement among brain tumor survivors in all three academic domains, reading, spelling, and arithmetic, though the extent of that impairment may vary.

Not only may the extent of impairment found between academic domains vary, the degree of overall academic impairment among survivors varies widely. Some children experience no impairment, others only mild, yet others demonstrate considerable deficits (Mulhern & Butler, 2004; Ris & Bebee, 2008; Reimers et al., 2003). Differences in the type of treatment a child received has been shown to account for a portion of the variability in academic outcomes, but additional moderating factors must be considered (Mabbott et al., 2005; Mulhern & Butler, 2004; Reddick et al., 2003). It has been suggested that family factors and environmental factors may further explain some of the variability in academic achievement outcomes seen among brain tumor survivors and should therefore be considered (Patel & Carlson-Green, 2005).
Treatment Factors that May Moderate Academic Outcomes for Brain Tumor Survivors

Treatment for nearly all forms of pediatric cancer disrupts normal academic routines and requires either short-term, or prolonged, absences from school. Treatment may require extended hospitalizations and have side effects such as pain, nausea, or fatigue that interfere with children’s ability to attend school and complete assignments regularly (Charlton et al., 1991). Not surprisingly, increased school absenteeism or sporadic attendance can be associated with poor academic progress (Lamdin, 1996). Although it might be expected that once children complete treatment and are able to resume regular school attendance their academic progress would normalize, this may not always be the case. For many brain tumor survivors, academic difficulties persist and may even worsen with time (Mulhern et al., 2004; Turner, Rey-Casserly, Liptak, Chordas, 2009).

Treatment protocols for pediatric brain tumors typically include neurosurgery, chemotherapy, or radiation and may involve a combination of the three depending on a child’s disease. Studies suggest that each of these treatment modalities places children at increased risk for various medical and neurocognitive impairments and late effects (Fuemmeler, Elkin, & Mullins, 2002; Gurney et al., 2003b; Mulhern & Butler, 2004; Radcliffe et al., 1994). Neurosurgery is typically the first line of treatment for children diagnosed with a brain tumor. The goal is to remove as much of the tumor as possible and prevent further growth and dissemination. Depending on their disease, some children may require adjuvant therapy, radiation and/or chemotherapy, following surgery in order to eradicate or slow tumor growth and extend survival (Levy, 2005; Packer, 2005). Other
children who are treated with neurosurgery experience full recovery and do not require adjuvant treatment, but may need rehabilitation, ongoing medical care, and periodical monitoring for disease recurrence.

Whether or not surgery is combined with chemotherapy and/or radiation, surgical resection itself carries risk of significant medical complications that may necessitate extended hospital stays followed by inpatient or out-patient rehabilitation (Kirk, Howard, & Scott, 1995). The neurocognitive functioning of children treated with surgery may be compromised by excess pressure placed on surrounding brain regions by the tumor mass itself, damage sustained to healthy tissue during surgery, or other peri-surgical complications including infection or swelling (Beebe et al., 2005; Steinlin et al., 2003). For example, posterior fossa syndrome occurs peri-operatively in approximately 15% of children with brain tumors (Kirk et al., 1995). This syndrome includes such symptoms as mutism, speech and motor disturbances, paralysis, and other sensorimotor impairments. These surgical complications can take months to remit and may significantly disrupt a child’s school attendance and functioning in the interim. Although a sizeable number of children with brain tumors “only” require surgical intervention, surprisingly little research has investigated their academic outcomes despite growing evidence that they too are at risk for long term neurocognitive morbidity (Aarsen et al., 2004; Beebe et al., 2005; Ris et al., 2008; Riva & Giorgi, 2000a, 2000b; Rueckriegel et al., 2009).

A recent study using advanced magnetic imaging techniques measured the extent of damage to the brain’s normal appearing white matter (health tissue) in three groups: (a) children with pilocytic astrocytoma who were treated with surgery only, (b) children with medulloblastoma treated with surgery and adjuvant therapy, and (c) healthy, age-
matched controls. Magnetic resonance imaging indicated that compared to healthy controls, children in both treatment groups evidenced significantly more loss or damage to normal appearing white matter. Perhaps more noteworthy is the diffuse pattern of white matter damage apparent among children treated for pilocytic astrocytoma with surgery only, suggesting that even surgery alone may be associated with physiological changes (Rueckriegel et al., 2009). As Reddick’s model posited, physiological changes may be associated with neurocognitive changes and have functional implications such as impaired academic achievement (Reddick et al., 2003).

Another study of children treated with neurosurgery alone for pilocytic astrocytoma found all 23 children in their sample experienced negative cognitive sequelae when assessed between 1 and almost 9 years post surgery (Aarsen, Van Dongen, Paquier, Van Mourik, & Catsman-Berrevoets, 2004). A significant inverse relationship was found between the severity, but not duration of pre-operative hydrocephalus, and children’s visual-spatial skills. This implies that it is not exclusively the direct tumor mass or surgical lesion that contributes to the cognitive impact, but that the rise in intracranial pressure pre-operatively may also contribute to long-term outcomes. Just a single study examining the academic achievement of children treated with neurosurgery only could be identified (Beebe et al., 2005). This study found significantly poorer spelling and arithmetic achievement, but not reading, compared to age referenced norms. However, the authors reported that approximately 35% of survivors’ reading scores fell at or below the 25th percentile.

Although limited research exists regarding the impact of surgery alone on brain tumor survivors, there is an extensive literature on the effects of radiation on children
treated for brain tumors and other forms of cancer. During the 1970’s cranial radiation therapy became a standard part of treatment protocols for children with brain tumors and leukemia (Lansky et al., 1984). Despite increased survival rates associated with this aggressive treatment approach, it was associated with considerable impairment among survivors (Lansky et al., 1984). Well-established findings demonstrate an association between radiation exposure and a number of morbidities, including deficits in core neurocognitive skills such as attention and executive function, and declines in academic achievement and overall IQ scores (Jain, Krull, Brouwers, Chintagumpala, & Woo, 2008; Packer, Cogen, Vezina, & Rorke, 1999). Results demonstrating that the more radiation a child received, the significantly greater likelihood they would utilize special education services prompted extensive research into the relationship between this mode of treatment and subsequent functioning (Mitby et al., 2003). Research later confirmed that the amount of radiation children received and the extent of their academic deficits were connected in a dose-response fashion (Palmer, Reddick, & Gajjar, 2007).

A third form of treatment often used in conjunction with surgery and radiation, but occasionally alone, is chemotherapy. Chemotherapy may be delivered systemically (oral/IV) or intrathecally in which the drugs are administered directly into the spinal fluid in order to penetrate the CNS (Levy, 2005). The same chemotherapy agents used to treat malignant brain tumors are also frequently used to treat other forms of cancer that can disseminate into the CNS (e.g., leukemia) and the majority of the research examining the impact of radiation and/or chemotherapy in the absence of neurosurgery comes from studies done with these children. A meta-analysis on the long-term neurocognitive functioning of survivors of childhood Acute Lymphocytic Leukemia (ALL) found
significant declines, relative to healthy controls, across all 13 global and specific neurocognitive domains examined, including academic achievement. ALL survivors who had received intrathecal and systemic chemotherapy to prevent CNS disease scored .42, .57, and .60 standard deviations below their controls (based on Hedges $g$) on the Spelling, Reading, and Arithmetic portions of the Wide Range Achievement Test, respectively (Campbell et al., 2007). The same meta-analysis of ALL survivors also found significantly lower academic achievement scores compared to healthy controls in children treated with a combination of chemotherapy and radiation. Though the majority of children treated for a brain tumor undergo neurosurgery, some tumors remain largely inoperable due to their location (e.g., brain stem) (Recinos, Sciubba, & Jallo, 2007). These children may be treated with radiation, chemotherapy, or a combination of the two.

Children undergoing multi-modal treatment may be at increased risk for treatment related morbidities. One research group compared the cognitive functioning of children treated with neurosurgery, radiation, and chemotherapy to that of a group of healthy, age-matched controls selected from among the patients’ siblings and first cousins. The children treated for a brain tumor performed significantly worse than controls on a range of neurocognitive tests (Riva et al., 2002). Another study found children treated with all three treatment modalities (i.e., surgery, chemotherapy, radiation) were not only exposed to greater amounts of radiotherapy than those receiving radiation or chemotherapy alone, but also had a 3x greater risk of experiencing an adverse medical outcome (e.g., stroke, blood-clot, osteoporosis, growth-hormone deficiency) compared to children treated with surgery or radiation alone (Gurney et al., 2003b). In summary, the negative impact of brain tumor treatment on children’s health, cognitive functioning, and subsequent
academic achievement is well documented, but may vary as a function of the specific treatment they received.

**Demographic and Family Environment Factors that May Moderate Academic Outcomes for Brain Tumor Survivors**

Despite evidence of the impact treatment variables have on neurocognitive functioning and academic achievement in brain tumor survivors, these factors do not fully account for the variability in academic achievement found among these children. Therefore, additional risk and protective factors, particularly family factors, that exert either a direct influence on a child’s academic achievement or moderate the impact of other factors (e.g., type of treatment) warrant consideration (Patel & Carlson-Green, 2005).

Bronfenbrenner’s (1989) social ecological model of child development offers support for the impact of family demographic and family environment factors on a child’s functioning. The model proposes that characteristics of the systems and environments in which the child is embedded (e.g., family environment, socioeconomic status, social support network, neighborhood, school, community) exert interactive and reciprocal influences on the child’s functional outcomes, including school performance and academic achievement (Bronfenbrenner, 1989). The application of Bronfenbrenner’s social ecological model to pediatric psychology and specifically children facing a cancer diagnosis has been advocated (Kazak, Rourke, & Navsaria, 2009).

There is longstanding support for a link between parental education and children’s academic achievement and progress. Data find that demographic variables, including
parental education levels and socioeconomic status (SES), account for a significant portion of the variance in children’s intellectual abilities and academic progress (Bakker, Denessen, & Brus-Laeven, 2007; Marjoribanks, 1980; Rosenzweig, 2001; Vanderploeg, Schinka, & Baum, 1998). A portion of the variability in academic functioning seen among children treated for a brain tumor may, therefore, be explained by family demographic or environmental differences. More highly educated parents are more likely to hold more prestigious or higher paying jobs, enabling the family to live in more affluent neighborhoods. Such areas are associated with greater access to educational resources and more enriched environments and schools for children and may foster enhanced academic achievement. More educated parents may also place a greater emphasis and value on education, development of academic skills, and promote stronger school engagement which is a well established predictor of academic achievement (Faulkner, Adlaf, Irving, Allison, & Dwyer, 2009; Goodenow & Grady, 1993; Voelkl, 1995).

Family variables moderating neurobehavioral among brain tumor survivors and other populations facing neurological impairment have been reported. In a sample of 63 children diagnosed with heterogeneous brain tumor diagnoses, Carlson-Green and colleagues (1995) explored the ability of family-related variables to predict children’s cognitive and behavioral outcomes, above and beyond illness factors, following treatment for a brain tumor. They found that a combination of illness and family variables (e.g., family stress level, number of parents in the home) was the strongest predictor of children’s intellectual functioning. Another study examined neighborhood influences on the academic achievement of children born at extremely low birthweights, another
population at risk for poor academic functioning. Findings showed demographic and family environment variables including parental education and parental protection exerted a significant and greater influence on children’s academic achievement than more distal factors such as neighborhood SES (Andreis et al., 2010).

Enriched home environments are more common among families with greater socioeconomic resources and higher parental education level and may be associated with more favorable cognitive and behavioral outcomes among pediatric cancer survivors. The impact of enriched environments on recovery following brain injury has been demonstrated in both animal studies in the laboratory and in children recovering from traumatic brain injury (TBI). Laboratory research has found that mice exposed to more enriched environments (i.e., those including novel materials and tasks to explore) following experimental brain lesions experienced greater behavioral and neural reorganization during recovery (Caleo, Tropea, Rossi, Gianfranceschi, & Maffei, 2009). Consistent with these findings, research with children recovering from TBI offers further support for the role family demographic variables may play in facilitating a child’s recovery. Taylor and colleagues (2002) found that lower socioeconomic status was more strongly associated with more negative behavioral sequelae in children recovering from TBI than for the control group (Taylor et al., 2002). This suggests higher SES families and more resource rich environments may be better able to compensate for the child’s deficits following a neurological insult than more resource poor environments (Mabbott et al., 2005; Mulhern & Palmer, 2003; Palmer, 2008; Palmer et al., 2007; Taylor & Alden, 1997).
Other qualities of the family environment, beyond socioeconomic status and parental education level, may further moderate a child’s academic achievement following a CNS insult (Taylor et al., 1999; Yeates et al., 2004). Among children recovering from TBI, socio-behavioral characteristics of the family environment, such as perceived caregiver burden and parenting practices, have been correlated with the rate and extent of the child’s recovery across several domains, including cognitive functioning and academic achievement (Taylor et al., 1999). Additionally, a measure of global family functioning, which takes into account family problem-solving, roles, communication, affective responsiveness and involvement, and behavioral control, was reported to be associated with intellectual functioning and memory in children recovering from TBI (Max et al., 1999). This suggests that the quality of the child’s family environment (e.g., amount of support and conflict within the family) may also contribute to children’s academic functioning after treatment for a brain tumor.

Better medical and psychological outcomes for children with cancer and other chronic illnesses have been found among families characterized by high levels of cohesion and low levels of conflict (Barkat, Pulargon, & Daniel, 2009). Despite calls to consider environmental factors that may moderate the long term functional impact of pediatric brain tumors on children, relatively little data currently exists on the topic (Patel & Carlson-Green, 2005). The current study seeks is to address this gap in the literature by examining potential the risk and protective factors that may moderate the extent of academic impairment demonstrated by children following treatment for a brain tumor, including types of treatment, demographic differences, and characteristics of the family.
environment. In addition, the current study addresses limitations of previous studies in this area including the lack of a control group and small sample sizes.

Whereas previous work has relied primarily upon the scores of norm referenced samples or siblings as control groups, the current design included a control group comprised of classmates matched for age, gender, and race as case-controls. Comparisons to instrument norms fail to account geographic differences, let alone for the unique educational opportunities and environments each brain tumor survivor has experienced. Although a sibling control group may address this shortcoming and control for similar educational environments, it fails to match on the basis of age and possibly gender. Ideally, the academic achievement of brain tumor survivors would be compared to children of their same age and gender and who have experienced similar educational environments and opportunities as the brain tumor survivor has. The use of classmates as controls affords such a comparison. Classmate-controls were matched one-to-one for each brain tumor survivor on the basis of age, gender, and race. For being classmates, these controls attend the same schools as the brain tumor survivors and are therefore likely to have experienced similar educational environments and opportunities. This direct matching of brain tumor survivors and classmate-controls allowed for matched-pair analyses which can increase statistical power to detect effects by controlling for systematic differences in academic achievement associated with educational opportunities and school environment. Thus, our analyses explored survivor achievement deficits based on discrepancies between each survivor and their individual classmate control who is not only demographically similar and shares an educational environment by attending the same school.
Among the current literature addressing the broader domain of neurocognitive sequelae among brain tumor survivors, just three studies with sample sizes greater than 54 could be found (Robinson et al., in press); the average sample size was $n = 34$. When limited to studies including measures of academic achievement, the average sample size was roughly $n = 40$ (Robinson et al., in press). Larger sample sizes are necessary in order to have sufficient power to detect small effect sizes. Additionally, larger samples are needed in order to examine moderation, or whether academic achievement varies as a function of treatment, demographic, or family environment factors. The current sample includes 164 brain tumor survivors.

Thus, as more children treated for brain tumors survive into adulthood, it is increasingly important to understand the factors contributing to survivors’ poorer academic outcomes. The implications of poor school performance are far-reaching and may impede survivors’ efforts to establish fulfilling careers or support themselves financially. This, in turn, compromises survivors’ abilities to lead independent lives and can negatively affect their long-term quality of life (Mulhern & Butler, 2004; Palmer, Reddick, & Gajjar, 2007; Rumberger, 1987).

**Aims and Hypotheses**

The first aim of this study was to compare the academic achievement of brain tumor survivors and classmate controls. It was hypothesized that brain tumor survivors would demonstrate lower levels of academic achievement relative to classmate controls and that survivors’ lower achievement would be evident across three specific academic domains: reading, spelling, and arithmetic. The magnitude of the effect sizes for different
domains were compared, although no a priori hypotheses were made in light of the conflicting literature.

The second aim of the study was to examine whether the magnitude of differences in academic achievement scores between survivors and classmate controls varied as a function of the treatment that the survivor had received. Brain tumor survivors were classified into three treatment groups according to the type of treatment they received: (a) neurosurgery only, (b) adjuvant treatment only, and (c) neurosurgery plus adjuvant treatment. In keeping with the study’s matched-pair design, discrepancy scores between the academic achievement scores of each brain tumor survivor and their classmate control were computed for all three academic domains and used in subsequent analyses. Negative discrepancy scores indicated that a brain tumor survivors’ achievement was below that of his or her classmate control; positive discrepancy scores signified the brain tumor survivor performed better than the classmate control. It was expected that survivors in all three treatment groups of would demonstrate significant deficits in achievement relative to their classmate controls, or that discrepancy scores would be significantly different from zero. However, the magnitude of these discrepancies was expected to vary between treatment groups such that children treated with neurosurgery only would fare better (i.e., exhibit less negative discrepancy scores) than the other two treatment groups.

The third aim of this study was to examine whether demographic variables including family SES, maternal education, and paternal education or family environment variables, such as the amount of support, conflict, or achievement orientation in the family moderated the impact of having a brain tumor on children’s academic
achievement relative to classmate controls (Figure 1). It was hypothesized that higher family SES and higher maternal/paternal education would be associated with less negative discrepancies in achievement between survivors and classmate controls across all three academic domains. Similarly, it was expected that less negative discrepancies in achievement would be associated with higher levels of supportiveness, lower levels of conflict, and a greater emphasis on achievement within families of brain tumor survivors.

The final aim of this study was to examine whether demographic and characteristics of the family environment moderated the impact of treatment type on discrepancies in academic achievement (Figure 2). It was hypothesized that the impact of treatment on academic achievement would be greater when survivors’ families were characterized by lower SES and lower maternal/paternal education levels. Similarly, it was expected that the impact of treatment on academic achievement would be greater when survivors’ families were characterized by less support, more conflict, and less emphasis on achievement orientation.

**Method**

**Procedures**

Brain tumor survivors were identified using local tumor registries at five pediatric oncology centers in the United States and Canada. Children were eligible if they: (a) were between 8-15 years old at the time of recruitment (inclusive), (b) had been previously diagnosed and treated for an intracranial tumor, and (c) had been off treatment for 1-5 years with no evidence of disease progression. All children lived within 100 miles of the medical center where they were treated. Children were excluded if they: (a) had any
preexisting neurobehavioral disorders, (b) were not fluent in English, or (c) were in a full-time special education classroom. Children who received part-time special education services were included provided they were in a mainstream classroom for at least one core academic subject (e.g., English, math, social studies).

Parents of eligible children received a letter introducing the study from their child’s primary oncologist or neurosurgeon. Study staff subsequently contacted parents to ascertain their interest in a school-based study of children’s friendships following treatment for a brain tumor. If parents agreed, the child’s principal was contacted to explain the study, answer questions, and obtain permission to collect data at the school. In collaboration with the primary teacher of elementary school students or the teacher of a required, core academic class for students in middle or high school, consent forms were distributed to classmates. Data were collected in a single, group classroom session led by trained research assistants. In order to protect confidentiality and reduce stigma and bias, no references were made to the students about the study’s focus on brain tumors or any particular student in the class.

A second phase of data collection involved individually administered assessments completed with each brain tumor survivor and their parents in the home. From among the classmates who participated in the classroom data collection, the child of the same gender, race, and closest in age to the brain tumor survivor was identified as a potential classmate control. The parents of this child were contacted and asked to participate in this second phase of the study. If the parents of a potential classmate control could not be reached or declined to participate, the next most closely matched classmate was contacted. Potential controls were excluded if they, or another child in the home, had
been treated for a severe or chronic illness, operationalized as a health condition requiring treatment by a medical specialist, for at least 6 months.

Brain tumor survivors and their classmate controls were matched on gender, race, and age and not explicitly on the basis of socioeconomic or family factors. Our method of selecting a classmate as a comparison attempts to control for the influence of educational environments and opportunities, family SES, and parental education level on a child’s academic achievement. This method is based on findings that classmates who live in similar areas and attend the same school are likely to come from similar demographic backgrounds and to have had similar educational experiences and opportunities (Noll et al., 1999).

During the home-based assessment, children in both groups (brain tumor survivors and classmate controls) completed a battery of assessments, including a standardized measure of academic achievement. Each caregiver residing in the child’s home was asked to complete a series of questionnaires describing the family’s sociodemographic characteristics and family functioning. If a mother or father living in the home declined to participate, information regarding their education and employment was obtained from the participating parent. Visits lasted approximately 2.5 hours, and families were compensated for their time. All consent/assent procedures and measures were approved by the Institutional Review Boards of each site.

Participants

Data were collected at five pediatric tertiary care centers in the United States and Canada. Across data collection sites, the families of 289 pediatric brain tumor survivors
were eligible and able to be contacted for the first phase of the study involving classroom data collection and the identification of potential classmate-controls. School data collection was successfully completed in the classrooms of 218 brain tumor survivors (75%). Subsequently, the families of 190 brain tumor survivors agreed to participate in the second, home visit, phase of the study. Families of 164 classmates of the brain tumor survivors, matched for gender, race, and age were recruited and completed assessments in their homes. The mean age of survivors and comparison classmates at the time of home data collection was 11.3 years ($SD = 2.3$) and not significantly different ($t [162] = 1.004$). Both groups of participating children included 76 girls (46%).

According to parent report, 85% of the brain tumor survivors in the sample were Caucasian ($n = 139$), 7% were African-American ($n = 11$), 1% were Asian ($n = 2$), and 7% belonged to another racial group ($n = 11$). In the classmate control group, 88% of the children were Caucasian ($n = 143$), 8% were African-American ($n = 13$), 1% were Asian ($n = 2$), and 3% belonged to another racial group ($n = 4$) according to parent report. The number of female caregivers who participated in home data collection was nearly identical for brain tumor survivors ($n = 153; 93\%$) and classmate controls ($n = 158; 96\%$). The number of male caregivers who participated was $n = 101 (62\%)$ for brain tumor survivors and $n = 92 (56\%)$ for classmate controls.

**Child Measures**

*Wide Range Achievement Test-3 (WRAT-3)*: The WRAT-3 (Wilkinson, 1993) is a brief (approximately 30 minutes) achievement test comprised of three subscales measuring reading recognition, spelling, and arithmetic computation skills. Standard scores, based
on age, have a mean of 100 and a standard deviation of 15. The WRAT has .98 split-half reliability for the reading subscale, .94 for arithmetic, and .97 for spelling (Wilkinson, 1993). Scores on the WRAT correlate moderately ($r = .40-.70$) with scores on other tests of academic achievement including the Woodcock-Johnson achievement subtests (Woodcock, 2001) and the Peabody Individual Achievement Test (Vance, Kitson, & Singer, 2006). In some instances, WRAT scores are suggested to overestimate actual school achievement since actual school achievement, typically measured by grades, may be due to factors beyond knowledge alone (e.g., turning in assignments, studying for tests) (Newville & Hamm, 1985).

**Parent Measures**

*Demographic Background Questionnaire:* This instrument obtains self-report of basic background characteristics of each participating parent (e.g., age, marital status, education level, occupation), the family (e.g., income, family size), and the participating child (e.g., date of birth, race). Socioeconomic status (SES) was computed using the Revised Duncan Scale (Nakao & Treas, 1992), a psychometrically valid measure that assigns SES scores based on 503 job codes derived from the 1989 U.S. Census data. In the event that only one parent of a two parent household participated, the participating parent provided the nonparticipating parent’s age, occupation, and educational background. When both parents were employed, the SES used to characterize the family reflects the higher of their two scores. While controversy exists regarding the optimal means of measuring family SES, Entwisle and Antone (1994) cite the use of the Nakao
and Treas indices as the best choice for determining SES based on job codes and discourage the use of reported income as a proxy for SES.

*Family Environment Scale (FES):* The FES (Moos & Moos, 1986) assesses the social environment within the family using 90 “true” or “false” questions. A widely accepted factor analysis of the FES finds three higher order factors: Supportive, Conflicted, and Controlling (Kronenberger & Thompson, 1990). The “Supportive” factor taps family concern, mutual interests, and support across domains, “Conflicted” offers an index of disorganization or lack of support present in the home, while “Controlling” refers to the use of rules and competition to shape family member behavior and foster a lack of independence among members. Scores on these three higher order factors are comprised of items from 10 subscales, one of which is Achievement Orientation. The current study utilized the “Supportive” and “Conflicted” factors and the “Achievement Orientation” subscale (which loads onto the Controlling factor). The internal consistency of the 10 subscales ranges from .61-.78 (Achievement Orientation: $\alpha = .64$). Test-retest reliabilities of the subscales at 2-month, 3-month, and 12-month intervals ranges from .52 -.93 suggesting the scale is reasonably stable over time (Moos & Moos, 1986). In the current study, internal reliability for both factors and the achievement subscale was acceptable. Based on mothers’ responses, Cronbach’s alpha was .94 for the supportive factor, .93 on the conflicted factor, and .83 on the achievement subscale. According to fathers’ responses, Cronbach’s alpha was .95 on the supportive factor, .94 on the conflicted factors, and .81 on the achievement orientation subscale.
Medical Data

Information regarding the brain tumor survivor’s diagnosis (e.g., tumor type, location), treatment received (i.e., neurosurgery, chemotherapy, or radiation), and time since treatment was abstracted from medical records maintained by the hospital and affiliated clinics.

Analysis Plan

Descriptive statistics were summarized for key medical variables, including diagnosis, child’s age at diagnosis, time since diagnosis, type of treatment received, and time since completing treatment. Descriptive statistics, matched-pairs t-tests, and Chi-square tests were used to summarize and compare demographic characteristics of brain tumor survivors and their classmate controls. This included child age, gender, race, family SES, and parental education levels. The first hypothesis that brain tumor survivors would demonstrate lower academic achievement scores compared to classmate controls in each academic area was tested using two tailed, matched-pair t-tests ($\alpha = .05$). Next, discrepancy scores between each brain tumor survivor (BT) and their classmate control (CC) were computed for all three academic domains:

- Mean Reading (R) Discrepancy = $D_R = BT_R - CC_R$
- Mean Spelling (S) Discrepancy = $D_S = BT_S - CC_S$
- Mean Arithmetic (A) Discrepancy = $D_A = BT_A - CC_A$

Negative discrepancy scores indicate that brain tumor survivors’ academic achievement is below that of the classmate controls in the given domain, while positive discrepancy scores indicate better performance by the brain tumor survivors relative to the classmate controls. Discrepancy scores closer to zero indicate academic achievement scores that are
more similar between the two groups. A one-way, within group ANOVA was then used to examine whether the magnitude of the within pair achievement discrepancy scores were significantly different across the three academic domains.

The second aim of the study was to examine the effect of treatment on survivors’ academic achievement relative to classmate controls. Brain tumor survivors were classified into three treatment groups based on the treatment they received: (a) neurosurgery only, (b) adjuvant treatment only, or (c) neurosurgery plus adjuvant treatment. It was hypothesized that all three treatment groups would perform worse than classmate controls (i.e., mean discrepancy scores would be negative). However, discrepancy scores were expected to be larger, or more negative, for brain tumor survivors who were treated with neurosurgery plus adjuvant treatment or adjuvant treatment alone relative to those treated with neurosurgery only. A between subjects, one-way ANOVA ($\alpha = .05$) with three levels examined whether there was a significant difference in discrepancy scores for survivors in the three treatment groups. Post-hoc tests using Fisher’s least significant difference test (LSD) were planned to determine which treatment groups differed significantly from one another if a significant overall F-statistic was found between treatment groups. This procedure was repeated for reading, spelling, and arithmetic.

The third aim of this study was to examine whether demographic and family environment variables moderated children’s academic achievement following treatment for a brain tumor. It was expected that discrepancies reflecting greater deficits in academic achievement among brain tumor survivors relative to classmate controls would be associated with lower family SES and lower parental education levels. In addition, it
was expected that these achievement deficits would be more negative, reflecting greater impairment among brain tumor survivors, when family support and achievement orientation were lower, and conflict was higher (Figure 1). Pearson correlations were computed between discrepancy scores for each academic domain and each family demographic variable (i.e., family SES, maternal education and paternal education) and each family environment variable (i.e., support, conflict, and achievement orientation). This approach allowed the moderator variables to remain continuous and the dependence of the matched pairs to be maintained. Each possible moderator variable was tested separately.

The final aim of the study was to determine whether demographic and family environment factors moderated the impact of treatment group on academic achievement discrepancy scores (Figure 2). Hierarchical linear regression analyses were used to examine these models. The first step of each regression model included a treatment group variable and the family demographic (i.e., family SES, maternal education level, paternal education level) or the family environment variable (i.e., support, conflict, achievement orientation) being tested. The second step of the regression model examined the significance of the interaction between treatment group and the family demographic or environment factor, indicating whether the impact of treatment on academic deficits varied as a function of the family demographic or environmental factor in question. The simple effect of each family factor on each treatment group and the interaction was examined using an Ordinary Least Squares method for probing interactions (Hayes & Matthes, 2009). This approach allows one to detect regions of significance, the range of values of the moderating predictor for which there were significant discrepancies in
academic achievement between treatment groups. This was repeated with each family
demographic and family environment variable for academic achievement in each of the
three academic domains. The current sample of 164 brain tumor survivor-classmate
control pairs had sufficient power ($1 - \beta = .72$) to detect small effect sizes between the
brain tumor survivor and classmate control groups. The current sample size also
provided sufficient power ($1 - \beta = .81$) to detect medium effect sizes between treatment
groups, but power to detect small effects was limited ($1 - \beta = .19$).

**Results**

**Family Characteristics of Brain Tumor Survivors and Classmate Controls**

Brain tumor survivors had a mean age at diagnosis of 7.8 years ($SD = 3.0$).

Inclusion criteria required that all brain tumor survivors had received treatment which
was completed treatment 1-5 years prior to recruitment. Home data collection occurred
an average of 2.9 years ($SD = 1.7$) since the child completed treatment. The most frequent
diagnosis in the sample was pilocytic astrocytoma ($n = 45; 27\%$) followed by
medulloblastoma ($n = 30; 18\%$). Table 1 summarizes the number of brain tumor survivors
in this sample treated with neurosurgery, chemotherapy, or radiation, as well as the
number of children in each of the three treatment groups used in the analysis: (a)
neurosurgery only, (b) adjuvant treatment only, or (c) neurosurgery plus adjuvant
treatment. The majority of brain tumor survivors in this sample were treated with
neurosurgery ($n = 143; 87\%$), $42\%$ received chemotherapy ($n = 69$), and $44\%$ received
radiation ($n = 72$) either alone or in combination with other treatment modalities. Nearly
half of the sample, $46\%$ ($n = 75$), underwent surgical resection of their tumors but did not
require additional, adjuvant, treatment with chemotherapy or radiation. Nearly half of the sample (47%; \( n = 77 \)) was treated with a combination of treatment modalities which may confer added risk of impairment (Gurney et al., 2003a).

Descriptive information regarding the demographic characteristics of brain tumor survivor and classmate control samples is summarized in Table 2. Brain tumor survivors and classmate controls were matched based on gender, race, and age and not explicitly on socioeconomic or family factors. Based on a Chi-square test, the racial composition of the brain tumor survivor group, according to parent report, was not significantly different from that of classmate controls \( \chi^2 (4, 163) = 64.35; p > .05 \). The groups differed significantly only on family SES though both means were reflective of occupations in technical, sales, and administrative support sector. As evident in Table 2, the two groups were markedly similar across all individual and family demographic variables suggesting the selection and matching criteria were effective.

For the purposes of this study, the terms “mother” and “father” are used to refer to the child’s primary female and male caregiver living in the home with the child. The majority of the participating caregivers identified themselves as the child’s biological parent. In both the brain tumor survivor and classmate control groups, 99% of the female caregivers were biological mothers. The remaining 1% identified themselves as step-mothers, adoptive mothers, or grandmothers. Among the male caregivers, 85% of the brain tumor survivor group and 91% of the classmate control group identified themselves as the child’s biological father. Of the remaining male caregivers who participated, step-fathers comprised 11% and 8% of the survivor and classmate control groups, respectively. The remaining male caregivers identified as having “other” relationships to
the child (e.g., adoptive, foster, or grandparent). Brain tumor survivors (76%; \( n = 123 \)) and classmate controls (83%; \( n = 135 \)) were more likely to live in two-parent families than single-parent families (Table 2). The number of single versus two-parent families who completed home data collection was not significantly different between the brain tumor survivor group and classmate controls (\( t [158] = -1.6; p = .12 \)).

**Group Differences in Academic Achievement**

Hypothesis one proposed that brain tumor survivors would demonstrate poorer academic achievement based on WRAT scores relative to classmates controls across all three academic domains. Mean academic achievement scores, mean discrepancy scores, and results of two-tailed matched-pair \( t \)-tests comparing the achievement scores of the brain tumor survivors and the classmate controls for each academic domain are presented in Table 3. Mean discrepancy scores for all academic domains were negative indicating that brain tumor survivors were demonstrating poorer achievement scores than their classmate controls (\( p \leq .001 \)). Discrepancy scores ranged from -55 to 35 for reading, -64 to 47 for spelling, and -66 to 37 for arithmetic. Across academic domains, the majority, 64-68\%, of the brain tumor survivor-classmate control pairs demonstrated negative discrepancy scores as expected.

Matched-pair \( t \)-tests indicated that mean academic achievement scores were significantly different between brain tumor survivors and classmate controls across all three academic domains (\( p \leq .05 \)). Effect sizes, Cohen’s \( d \) ranging from -.32 to -.45 were calculated assuming independent samples and are included in Table 3. This approach of assuming independence between groups results in a more conservative estimate of effect.
size than assuming dependence and has been recommended as a safeguard against inflated effect size estimates (Dunlap, Cortina, Vaslow, & Burke, 1996). If the less conservative approach of assuming group dependence was used, the discrepancies reflect medium effect sizes \( d = -0.57 \) for reading, \( d = -0.53 \) for spelling, and \( d = -0.76 \) for arithmetic) (Cohen, 1988).

A one-way, within subject ANOVA was used to test the magnitude of deficits observed for reading, spelling, and arithmetic domains (see Table 3). The dependent variable in this analysis was the mean discrepancy score calculated based on survivor-classmate control dyads (e.g., Mean Reading (R) Discrepancy = \( D_{\text{R}} = BT_{\text{R}} - CC_{\text{R}} \)). Results of the one-way, within subject ANOVA found no significant differences in the discrepancy scores between each of the academic domains \( F[2,326] = 1.59; p = .21 \).

**Role of Brain Tumor Treatment as a Moderator of Group Differences in Academic Achievement**

The second aim of the study was to examine the effect of treatment type on the academic achievement of brain tumor survivors. The means and standard deviations of achievement scores for survivors and controls, as well as, the mean discrepancy scores for each treatment group are presented in Table 4. The mean discrepancy score for each treatment group in each academic domain was negative indicating that, on average, brain tumor survivors demonstrated lower academic achievement than classmate controls. Between subjects, one-way ANOVAs with three levels, tested whether treatment group differences in discrepancy scores were significant for each academic domain. None of these differences reached statistical significance (see Table 4). Given concerns about the
small size of the adjuvant only group \((n=20)\), direct comparisons were also made between the larger neurosurgery only and neurosurgery plus adjuvant therapy groups. The two groups show a trend towards significance for reading, \(F(142) = 3.73, p = .056\), and arithmetic, \(F(142) = 3.73, p = .055\), but not for spelling, \(F(142) = .79, p = .376\). The academic achievement discrepancy scores of brain tumor survivors treated with neurosurgery only is significantly different from zero for arithmetic, \(t(74) = -2.11, p = .038\), but not spelling, \(t(74) = -1.83 p = .071\), or reading, \(t(74) = -1.26, p = .211\).

**Role of Family Characteristics as Moderators of Group Differences in Academic Achievement**

The third aim of the study was to examine whether demographic variables and characteristics of the family environment moderated the impact of brain tumors and their treatment on survivors’ academic achievement. Analyses were planned to examine whether the academic deficits experienced by brain tumor survivors, measured by achievement discrepancy scores, varied as a function of factors such as family SES, the amount of education a parent has completed, or the extent of family support, conflict, or achievement orientation in the home. Table 5 provides the correlations between achievement discrepancy scores for each academic domain and family demographic variables. Contrary to what was hypothesized, neither maternal nor paternal education level was significantly associated with the magnitude of discrepancies found between the academic achievement scores of brain tumor survivors and classmate controls. One significant positive correlation for brain tumor survivors indicated that higher family SES was correlated with less negative reading discrepancy scores for survivors. This suggests
that as survivors’ family SES increases, the magnitude of the discrepancy in reading scores between brain tumor survivors and classmate controls becomes less negative and brain tumor survivors performed more similarly to their classmate controls. The association between survivor family SES and reading discrepancy scores among brain tumor survivors is presented in Figure 3. Evidence for the benefit of higher SES was not found in achievement discrepancies for spelling or arithmetic domains.

Parents completed the Family Environment Scale (FES) and rated the degree of support, conflict, and achievement orientation present in their homes. Table 6 presents the correlations between academic achievement discrepancy scores and these characteristics of the family environment. Significant correlations were found between academic achievement discrepancy scores across all three academic domains for both mother and father ratings on the support and conflict scales of the FES. The more support parents reported in the family, the less negative the discrepancy scores. This suggests that brain tumor survivors living in homes with more supportive families demonstrated less academic impairment than survivors living in less supportive home environments. Similarly, the more conflict parents reported, the more negative the discrepancy scores indicating that brain tumor survivors experience greater academic impairment the more conflict parents report there to be in the home. Neither mother nor father ratings of the family’s emphasis on academic and intellectual pursuits, measured by the achievement orientation scale, was significantly related to discrepancy scores.

**Role of Family Environment Characteristics as Moderators of the Impact of Brain Tumor Treatment**
The final aim of the study was to examine whether the impact of treatment type on brain tumor survivors’ achievement deficits was moderated by family characteristics. A "low intensity” treatment group was defined as survivors treated with neurosurgery only and the “high intensity” group reflected those treated with neurosurgery plus adjuvant treatment. The scores provided by children in the adjuvant only group were excluded from the analysis based on the small sample (n = 20).

A series of hierarchical linear regression models were examined in which treatment group (i.e., low or high intensity) and the demographic (i.e., family SES, maternal/paternal education level) or family environment variable (i.e., level of support, conflict, achievement orientation) were entered in the first step and the interaction term (i.e., high treatment intensity x family environment variable) in the second step. Results are presented in Tables 7 – 9. Significant interactions were not found between family demographic variables (i.e., family SES or parental education) and treatment group. Similarly, no significant interactions were found between treatment group and family environment variables in regression models predicting academic achievement discrepancy scores. The only model providing evidence of moderation of treatment group differences was in the prediction of spelling discrepancy scores by the interaction of treatment group and mother’s ratings of academic orientation. Analysis of regions of significance indicated that deficits in spelling achievement were significantly greater for brain tumor survivors who had received multi-modal treatment versus neurosurgery alone when mother’s rating of achievement orientation fell between 1 and 2.5 on a 10 point scale where lower scores reflect lower levels of achievement orientation. This FES score
fell at the 5\textsuperscript{th} percentile in this sample of brain tumor survivors and fell 1.5 standard deviations below the mean.

**Discussion**

Over the past several decades, improved detection and more aggressive treatment protocols have resulted in an increasing number of children diagnosed with brain tumors who survive into adulthood (Gurney et al., 1999; Packer, 2005). Many of these children experience neurocognitive impairment (Mulhern, et al., 2004) and associated functional deficits that may have long-term implications for their occupational and social functioning (Levin Newby, et al., 2000; Mostow et al., 1991). Academic achievement is one area that may be negatively affected by the disease and its treatment. Poor academic achievement has been shown to have far reaching consequences as it has been linked to lower high school graduation rates, increased rates of unemployment, and diminished earning potential, all of which may compromise survivors’ long term quality of life (Mulhern & Butler, 2004; Rumberger, 1987). However, the extent of cognitive impairment experienced by brain tumor survivors varies widely (Jain et al., 2008; Packer et al., 1999).

The purpose of the current study was to better understand the role of risk and protective factors, including differences in treatment received, demographic, and family environment characteristics that may explain this variability in academic impairment. This information is crucial for the development and evaluation of treatment and direct interventions aimed at minimizing the long term impairment found in this growing group of survivors. In keeping with these study aims, the cohort of brain tumor survivors
recruited for this study was both demographically and medically diverse. Survivors were recruited from multiple pediatric institutions each of which serves diverse populations. This diversity assured variability with respect to family characteristics within the sample. Survivors had been treated for a variety of intracranial tumors and had achieved stable or disease-free status through varying single or multi-modal treatment regimens. The study design involved the recruitment of classmate controls, who were matched not only on child demographic characteristics (i.e. gender, race, and age) but attended the same schools and experienced similar educational environments and opportunities as a result. The two groups were well matched, increasing our ability to detect smaller effect sizes. Our evaluation of the effects of treatment, demographic, and characteristics of the family environment was completed based on discrepancies in academic achievement scores between brain tumor survivors and their classmate controls.

As expected, brain tumor survivors demonstrated poorer academic achievement than classmate controls in all three academic domains assessed (i.e., reading, spelling, and arithmetic). These findings are consistent with research that finds children receiving CNS directed treatment are at particular risk for achievement deficits (Barrera et al., 2005; Mostow et al., 1991; Reimers et al., 2003). Effect sizes, when calculated using a conservative of approach of assuming independence between the two groups, were small to medium sized according to Cohen (1988) and ranged from -.35 to -.45. A less conservative approach recognizing dependence between the groups produced medium effect sizes ranging from -.53 to -.76. It is likely that the true effect size lies somewhere between these two estimates which would be consistent with a recent meta-analysis that reported small to medium effect sizes for academic achievement of brain tumor survivors.
versus normative data in reading (-.45), spelling (-.63), and arithmetic (-.60) (Robinson et al., in press). These medium effect sizes are cause for concern and warrant continued attention. Although the achievement gap between brain tumor survivors and their classmate controls may be modest at an average of 2.9 years ($SD = 1.7$) post-treatment, the literature suggests that this divide will widen with increasing time (Barrera et al., 2005). Thus, brain tumor survivors are at risk of falling further and further behind their peers. It is likely this achievement gap is a precursor to the more distal outcomes including diminished educational attainment, lower graduation rates, and higher rates of unemployment reported among brain tumor survivors (Mulhern & Butler, 2004; Rumberger, 1987). Recognizing the long-term implications of this gap early may prove beneficial in curbing its growth.

The magnitude of the academic achievement deficits found in the current study did not vary significantly by academic domain indicating that all three academic areas were similarly affected among brain tumor survivors. In the current literature, there are mixed findings as to whether academic areas are equally affected following treatment for a brain tumor or whether certain domains may be more negatively affected than others. Some studies suggest that arithmetic skills may be most impaired, particularly in children treated with radiation (Copeland et al., 1988; Ochs et al., 1991). Other studies suggest reading achievement, and the core skills for phonological decoding may be more vulnerable to the effects of a brain tumor than spelling or arithmetic (Mabbot et al., 2005; Palmer, 2008). Although not significantly different, the effect size reflecting group differences in arithmetic was somewhat greater than for reading or spelling (Table 3). When examined based on treatment group, the largest effect was found in the arithmetic
domain among the children treated with neurosurgery plus adjuvant therapy ($d = -.66$), but differences with effects of children treated with neurosurgery ($d = -.29$) or adjuvant therapy ($d = -.25$) alone failed to reach statistical significance (Table 4).

The overarching aim of the study was to better understand whether treatment and family factors moderate or account for variability in academic achievement demonstrated by brain tumor survivors. The current study found no significant main effects of treatment on achievement deficits. The mean academic achievement discrepancy scores for brain tumor survivors and classmate controls were negative across all three treatment groups and all three academic domains (Table 4). This indicates that that brain tumor survivors, regardless of the type of treatment they received, were experiencing academic impairment relative to classmate controls. Examination of effect sizes revealed differences by treatment group and were consistent with the literature suggesting greater impairment is associated with increasing amounts of or complexity of treatment. Conservative effect size estimates, assuming independence between survivors and classmate controls, for the neurosurgery plus adjuvant therapy group was nearly twice the magnitude of those found in the neurosurgery only group. Effect sizes for the neurosurgery only group were small, (Cohen’s $d$ ranged from -.18 to -.29), small for the adjuvant only group (Cohen’s $d$ ranged from -.25 to -.47), and small to medium for the neurosurgery plus adjuvant therapy (Cohen’s $d$ ranged from -.39 to -.67) group. The current sample had sufficient power ($1-\beta = .81$) to detect medium sized differences ($d = .5$) between treatment groups, but power to detect small effects ($d = .2$) was limited ($1-\beta = .19$).
Previous research has highlighted the risks associated with radiation, chemotherapy, and multimodal treatment protocols including neurosurgery on subsequent cognitive functioning (Jain et al., 2008; Packer et al., 1999, Campbell et al., 2007). However, little is known about the academic functioning of children treated with neurosurgery only. The limited available research on this “surgery only” group suggests these children do experience significant morbidities following surgical treatment for their disease, and there have been numerous calls for further study in this area (Rueckriegel et al., 2009; Ris et al., 2008; Beebe et al., 2005; Aarsen et al., 2004; Steinlin et al., 2003 Riva & Giorgi, 2000a, 2000b). A strength of the current research is its inclusion of a large number (n = 75) of these understudied children who did not require chemotherapy or radiation. Although the effect sizes were small (Cohen’s $d$ ranged from -.18 to -.29), relative to classmate controls, the children treated with neurosurgery demonstrated lower academic achievement across all three academic domains than classmate controls.

The mechanisms responsible for the achievement deficits exhibited by this group of survivors treated with surgery alone are not well understood. It has been suggested that damage to healthy brain tissue caused by the tumor mass itself or incurred during the resection procedure may account for these deficits (Reddick et al., 2003). Tissue damage may also result from increased intracranial pressure, swelling, or inflammation, again, stemming from the tumor mass or the resection procedure (Aarsen et al., 2004; Steinlin et al., 2003). Physiological changes in Normal Appearing White Matter (NAWM) volume among children treated with neurosurgery alone have been linked with impaired cognitive functioning (Reddick et al., 2003; Rueckriegel et al., 2009; Zhang et al., 2008). Whether these changes are a result of the surgery or disease related processes remains
unknown. Interestingly, this same pattern has been increasingly investigated as a process mediating the effects of radiation on neurocognitive outcomes (Reddick et al., 2005). Thus, the current findings are consistent with the existing, albeit sparse, literature which suggests that children treated with neurosurgery, without chemotherapy or radiation, are still at risk for significant impairment. Thus, we echo the calls for further investigation in this area.

Our final two aims were to examine whether demographic or family environment characteristics moderated the impact of having a brain tumor on academic achievement discrepancy scores and whether there was a significant interaction between the intensity of a child’s treatment and demographic or family environment characteristics. Surprisingly, family demographic factors (i.e., family SES, parental education level) played almost no role in moderating achievement discrepancy scores between brain tumor survivors and classmate controls. Just one significant relationship was found between survivor family SES and reading discrepancy scores; higher family SES was correlated with smaller deficits in reading for survivors relative to their classmate controls (Figure 3). Palmer (2007) proposed a model in which deficits in skills believed to underlie reading (e.g., poor auditory attention, phonological processing and sequencing) serve to explain the impaired reading achievement demonstrated by brain tumor survivors. This research group has suggested that remedial training and repetition of phonologic skills may reduce reading deficits in survivors. Conceivably, higher SES families may have more time and resources to devote to helping the brain tumor survivor develop reading skills perhaps by focusing on the underlying skills. The relative lack of significant findings in the current study contradicts previous work that finds higher
family SES and higher parental education levels associated with higher academic performance among children surviving brain tumors (Palmer, 2008, Vanderploeg et al., 1998). One possible explanation for this lack of significant effects for parental education or SES is that the effects of these factors were attenuated by the matched pair design. While brain tumor survivors and classmate controls were not specifically matched on these variables, similarity in socioeconomic factors would be expected for children attending the same school. Previous studies have relied on alternative means of measuring family SES such as a composite based on maternal education and median income of the census tract in which the family resides (Yeates et al., 2010), the Hollingshead Index, or the Socioeconomic Composite Index (Taylor et al., 1999) rather than examining separate indicators of occupational prestige or parental education the current study.

Although family demographic characteristics were largely unrelated to the magnitude of achievement discrepancy scores, mother or father report of family environment characteristics (i.e., degree of support and conflict) significantly moderated the extent of academic impairment demonstrated by brain tumor survivors across all three academic domains. As the amount of support in the home increased, achievement discrepancy scores, across all three academic areas, became less negative, with survivor achievement scores approaching those of their healthy peers. In other words, the more support in the home, the less academic impairment the survivor demonstrated. Conversely, the more conflict either parent reported in the home, the more negative the discrepancy scores were across all three academic areas. These results are in keeping with the role of home environment, especially the negative impact of conflict, on the
cognitive functioning of children with TBI (Gerrard-Morris et al., 2010; Max et al., 1999; Taylor et al., 1999). It is possible that families reporting greater levels of support are more able to provide the brain tumor survivor with extra time, attention, and assistance in developing academic skills and completing their school work. This additional time and support may be necessary in helping the child compensate for the impairment they are experiencing following treatment for a brain tumor. Additional time, instruction, practice, homework help, tutoring, or academic assistance may maximize the child’s potential to master the academic material. Additionally, families reporting more support in the home may be more likely to spend time engaged in activities that foster a child’s intellectual development, self esteem, and self-efficacy. These factors have been found to be important indicators of academic performance (Marsh & Martin, 2010).

In contrast, the greater amount of conflict in the home may reflect less caregiver agreement over how to best support the child’s success or greater parental stress levels. High parental stress may result in parents having less time available to devote to the child’s academic needs following treatment for a brain tumor. Further research would be needed to investigate whether the availability of parental time and attention accounted for the impact of family conflict on the academic achievement of brain tumor survivors. Another possibility is that children coming from more supportive and less conflicted homes have greater pre-morbid academic functioning. As a result, any decline in their achievement following treatment for a brain tumor would perhaps leave them appearing less impaired than a counterpart from a highly conflicted, low support home who may have been experiencing poor achievement pre-morbidly (Ghazarian & Buehler, 2010).
These findings suggest that modifiable environmental factors may influence recovery or maintenance of academic functioning in brain tumor survivors. The mechanisms through which these relationships occur remains unclear and warrants further investigation so focused intervention programs can be developed. The reciprocal nature of children’s behavior and needs and family environment should be noted as demands placed by a child’s needs or deficits may influence the levels of support and conflict within a family. A longitudinal design would be necessary in order to more fully understand this relationship.

No significant interactions between treatment intensity and family factors on the discrepancy scores in any academic area were found, with one exception: mother’s rating of achievement orientation and treatment intensity when predicting spelling discrepancy scores. In that case, stronger differences between treatment groups in spelling impairment were found when there was less emphasis on achievement orientation in the families of the brain tumor survivor. In all other cases, the impact of treatment intensity on academic impairment did not vary as a function of family achievement orientation, supportiveness, or conflict. However, we had limited power to detect small effects (1 - β = .30).

As a first step in subsequent work, the results of the current study need to be replicated and some of its limitations noted. The inclusion of classmate controls matched for gender, age, and race was a strength of this study and allowed data to be analyzed using a matched-pair design. However, the use of a matched-pair design required data from both a brain tumor survivor and their classmate control in order to be included in the analyses which forced a number of brain tumor survivors to be dropped from the sample due to missing classmate control data. This loss of data is a drawback to the matched-pair
design and could be viewed as a study limitation. Another strength of the current study was its large sample size. Previous research with this population has suffered from limited sample sizes. Despite this strength, the sample was still too small to have sufficient power to detect small effects, so larger samples are still needed. Once the current sample was broken down into specific treatment groups, small cell sizes resulted in limited power to detect treatment-related effects or significant interactions between treatment severity and demographic or family environment characteristics. Therefore, future studies involving larger samples for each treatment group, with particular attention paid to the outcomes and needs of children treated with neurosurgery alone, would facilitate a better understanding of the impact various treatments have on academic achievement. While this group of children treated with neurosurgery alone demonstrated somewhat less academic impairment than children treated with multimodal therapies, results were not conclusive. With increasing time since treatment, their deficits could increase and therefore warrant attention.

Future studies might consider the role of additional child and medical variables that may serve as risk or protective factors; factors such as gender and age at treatment. There is a sizeable literature examining the role of child’s age at treatment which suggests younger children may be more negatively affected by treatment, particularly radiation (Reimers et al., 2003; Mulhern et al., 2001). Medical variables such as whether the child experienced surgical complications, required shunts to relieve intracranial pressure, experiences ongoing seizures, disease relapse, or other peri-surgical complications have been suggested to influence morbidity and therefore ought to be considered (Beebe et al., 2005; Steinlin et al., 2003).
In order to be eligible for this study, brain tumor survivors had to be in a mainstream classroom for at least one, core academic subject. Therefore, the current sample reflects a subset of brain tumor survivors who are functioning reasonably well and do not require more intensive, full time, special education services. Based on educational philosophies and legislation mainstreaming children, placing children with disabilities in classrooms with peers who are not disabled, is paramount (34 Code of Federal Regulations (C.F.R.) Sec. 300.550(b)(1) and (2); 20 U.S.C. Sec. 1412(a)(5)(A)). As such, children are placed in mainstream classrooms whenever possible, even if only for a portion of their day. Therefore, mainstreamed children reflect a broad range of ability levels. The current findings are not generalizable to brain tumor survivors who are not able to be mainstreamed. Had the sample included children too impaired to be mainstreamed, effects might have been strengthened. However, even among this group of mainstreamed survivors, the data show they too are experiencing significant academic deficits relative to their classmate controls and therefore warrant continued attention.

While the current study used an empirically validated and internally consistent measure of family environment, future studies might consider including child report of family environment, instead of relying entirely on parental self report. In addition, future studies might consider operationalizing family environment based on observations as well as the reports of multiple informants.

Increased understanding of which children are at greatest risk of poor academic achievement following treatment for a brain tumor will also aid health care providers, schools, and families in titrating appropriate services towards children in greatest need of interventions in order to minimize academic impairment. Resources within hospitals and
school settings may be limited and therefore could be prioritized and directed towards those in greatest need, perhaps those from families with high levels of conflict and low levels of support. A greater understanding of the role risk and protective factors, specifically demographic and environmental factors, play in children’s functioning following a brain tumor may also inform the development of family based interventions aimed at shaping the home environment and altering family dynamics to best facilitate the child’s rehabilitation following treatment for a brain tumor.

The limited intervention research available has focused on pharmacotherapy (Thompson et al., 2001) and cognitive rehabilitation programs (Butler & Copeland, 2002) both aimed at remediating the attentional problems many survivors exhibit and which are thought to underlie poor academic performance. One commercially available, computer based intervention, Fast ForWord, that targets impaired language and reading skills has been shown to be effective among children with specific language disabilities and other comorbid diagnoses including attention-deficit hyperactivity disorder and holds promise among pediatric brain tumor survivors (Palmer, Reddick, & Gajjar, 2007). Intervention programs targeting characteristics of the family environment could not be found but should be considered in future work. Perhaps a tailor approach in which families complete the module(s) that best address their current needs (e.g., a high conflict family may complete the module focused on reducing family conflict) would be both efficient and effective.

In conclusion, continued research aimed at minimizing the impact of treatment and subsequent impairment, maximizing functioning, and enhancing the ability of
survivors to lead fulfilling, independent, and productive lives is critical following the significant increase in survival rates this group of children now experiences.
References


Federal Regulations: 34 Code of Federal Regulations (C.F.R.) Sec. 300.550(b)(1) and (2); 20 U.S.C. Sec. 1412(a)(5)(A)


APPENDIX A: Tables
Table 1.

*Treatment frequencies for Brain Tumor Survivors (N = 163)*

<table>
<thead>
<tr>
<th>Treatment Groups</th>
<th>n</th>
<th>Percentage of Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Neurosurgery Only</strong>&lt;sup&gt;a&lt;/sup&gt;</td>
<td>75</td>
<td>46.0</td>
</tr>
<tr>
<td><strong>Adjuvant Only</strong>&lt;sup&gt;b&lt;/sup&gt;</td>
<td>20</td>
<td>12.3</td>
</tr>
<tr>
<td>Chemotherapy Only</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Radiation Only&lt;sup&gt;c&lt;/sup&gt;</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Chemotherapy + Radiation</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td><strong>Neurosurgery + Adjuvant</strong></td>
<td>68</td>
<td>41.7</td>
</tr>
<tr>
<td>Neurosurgery + Chemotherapy</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Neurosurgery + Radiation</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>Neurosurgery + Chemotherapy + Radiation</td>
<td>44</td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup> Full or partial resection  
<sup>b</sup> Whole brain or focal radiation  
<sup>c</sup> Chemotherapy and/or radiation
Table 2.

*Comparison of family and parental demographics between Brain Tumor Survivors and Classmate Controls (n = 164)*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Brain Tumor Survivors</th>
<th>Classmate Controls</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>Mothera</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>36.5</td>
<td>13.1</td>
<td>40.9</td>
<td>6.1</td>
</tr>
<tr>
<td>Educationb</td>
<td>14.2</td>
<td>2.2</td>
<td>13.4</td>
<td>4.3</td>
</tr>
<tr>
<td>Fathera</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>41.9</td>
<td>6.3</td>
<td>42.7</td>
<td>6.6</td>
</tr>
<tr>
<td>Education</td>
<td>14.2</td>
<td>2.6</td>
<td>14.7</td>
<td>2.6</td>
</tr>
<tr>
<td>Family</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SESc</td>
<td>53.4</td>
<td>21.2</td>
<td>58.0</td>
<td>21.9</td>
</tr>
<tr>
<td>Income</td>
<td>72,700</td>
<td>4,500</td>
<td>78,700</td>
<td>4,700</td>
</tr>
<tr>
<td>Family Structure</td>
<td>n</td>
<td>%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single Parent Family</td>
<td>41</td>
<td>24</td>
<td>28</td>
<td>17</td>
</tr>
<tr>
<td>Two Parent Family</td>
<td>123</td>
<td>76</td>
<td>135</td>
<td>83</td>
</tr>
</tbody>
</table>
$^a$ $n$ ranges from 92 to 153 for the number of mothers and fathers with responses included in this data.

$^b$ Number of years of education completed

$^c$ SES calculated based on Revised Duncan Scores of occupational prestige; when both parents reported occupations, the higher was used.

* $p < .05$
Table 3.

Comparison of academic achievement between Brain Tumor Survivors and Classmate Controls

<table>
<thead>
<tr>
<th>WRAT&lt;sup&gt;a&lt;/sup&gt; Subscale</th>
<th>Brain Tumor Survivors</th>
<th>Classmate Controls</th>
<th>Mean Discrepancy&lt;sup&gt;b&lt;/sup&gt;</th>
<th>t</th>
<th>p</th>
<th>df&lt;sup&gt;c&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reading</td>
<td>100.8 15.2</td>
<td>105.8 13.2</td>
<td>-4.98</td>
<td>-3.63</td>
<td>.000</td>
<td>-.35</td>
</tr>
<tr>
<td>Spelling</td>
<td>99.3 15.5</td>
<td>104.1 14.2</td>
<td>-4.82</td>
<td>-3.38</td>
<td>.001</td>
<td>-.32</td>
</tr>
<tr>
<td>Arithmetic</td>
<td>93.5 17.0</td>
<td>100.5 13.9</td>
<td>-6.93</td>
<td>-4.85</td>
<td>.000</td>
<td>-.45</td>
</tr>
</tbody>
</table>

<sup>a</sup>Wide Range Achievement Test – WRAT- based on age referenced standard scores

<sup>b</sup>Difference in mean scores between survivors and controls for each academic domain (i.e. Mean Reading<sub>BTS</sub> - Mean Reading<sub>CC</sub>)

<sup>c</sup>Cohen’s $d$ estimating effect size as if independent groups (Dunlap et al, 1996); df = 163
Table 4.

Comparison of academic achievement between treatment groups of Brain Tumor Survivors (N=163)\textsuperscript{a}

<table>
<thead>
<tr>
<th>WRAT\textsuperscript{b} Subscale</th>
<th>Neurosurgery Only (n = 75)</th>
<th>Adjuvant Only (n = 20)</th>
<th>Neurosurgery + Adjuvant (n = 68)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean  SD Discrepancy</td>
<td>Mean  SD Discrepancy</td>
<td>Mean  SD Discrepancy</td>
</tr>
<tr>
<td></td>
<td>M    SD</td>
<td>M    SD</td>
<td>M    SD</td>
</tr>
<tr>
<td>Reading</td>
<td>BTS\textsuperscript{c}</td>
<td>102.4 14.1 -2.3</td>
<td>100.7 17.4 -5.7</td>
</tr>
<tr>
<td></td>
<td>CC\textsuperscript{d}</td>
<td>104.8 12.5</td>
<td>109.2 11.5</td>
</tr>
<tr>
<td>Spelling</td>
<td>BTS</td>
<td>100.3 14.6 -3.6</td>
<td>99.4 14.9 -4.7</td>
</tr>
<tr>
<td></td>
<td>CC</td>
<td>104.0 13.6</td>
<td>106.1 12.6</td>
</tr>
<tr>
<td>Arithmetic</td>
<td>BTS</td>
<td>95.3 16.6 -4.6</td>
<td>93.7 15.8 -3.3</td>
</tr>
<tr>
<td></td>
<td>CC</td>
<td>100.7 14.4</td>
<td>97.7 13.6</td>
</tr>
</tbody>
</table>

\textsuperscript{a} Treatment data was missing for one subject
\textsuperscript{b} Wide Range Achievement Test-WRAT-based on age referenced standard scores
\textsuperscript{c} Brain Tumor Survivors-BTS
\textsuperscript{d} Classmate Controls-CC
\textsuperscript{e} F statistics from 3-way ANOVA (df = 160)
\textsuperscript{f} p-value for 3-way ANOVA
Table 5.

*Correlations between academic achievement discrepancy scores and family demographic variables (N = 164)*

<table>
<thead>
<tr>
<th>WRAT&lt;sup&gt;a&lt;/sup&gt; Subscale Discrepancy&lt;sup&gt;b&lt;/sup&gt;</th>
<th>Survivor Family SES&lt;sup&gt;c&lt;/sup&gt; (r)</th>
<th>Mother Education (r)</th>
<th>Father Education (r)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reading</td>
<td>.18*</td>
<td>-.01</td>
<td>.06</td>
</tr>
<tr>
<td>Spelling</td>
<td>.12</td>
<td>.01</td>
<td>.13</td>
</tr>
<tr>
<td>Arithmetic</td>
<td>.12</td>
<td>.03</td>
<td>.10</td>
</tr>
</tbody>
</table>

<sup>a</sup>Wide Range Achievement Test – WRAT- based on age referenced standard scores
<sup>b</sup>Correlations based on discrepancy scores. Discrepancy scores are the difference in mean scores between survivors and controls for each academic domain (i.e. Mean Reading<sub>BTS</sub> - Mean Reading<sub>CC</sub>)
<sup>c</sup>SES based on Revised Duncan Scores of occupational prestige; when both parents reported occupations, the higher of the two was used.

*Correlation significant at p<.05, two-tailed
Table 6.

Correlations between academic achievement discrepancy scores and parent ratings of family environment factors

<table>
<thead>
<tr>
<th>WRAT(^{b}) Subscale Discrepancy(^{c})</th>
<th>FES(^{a}) Scale</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Support</td>
<td>Conflict</td>
</tr>
<tr>
<td><strong>Mother</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reading</td>
<td>.19*</td>
<td>-.17*</td>
</tr>
<tr>
<td>Spelling</td>
<td>.16*</td>
<td>-.19*</td>
</tr>
<tr>
<td>Arithmetic</td>
<td>.17*</td>
<td>-.18*</td>
</tr>
<tr>
<td><strong>Father</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reading</td>
<td>.22*</td>
<td>-.23*</td>
</tr>
<tr>
<td>Spelling</td>
<td>.21*</td>
<td>-.26*</td>
</tr>
<tr>
<td>Arithmetic</td>
<td>.23*</td>
<td>-.20*</td>
</tr>
</tbody>
</table>

\(^{a}\)Family Environment Scale-FES
\(^{b}\)Wide Range Achievement Test-WRAT- based on age referenced standard scores
\(^{c}\)Discrepancy scores are the difference in mean scores between survivors and controls for each academic domain (i.e.\(\text{Mean Reading}_{\text{BTS}}-\text{Mean Reading}_{\text{CC}}\))

*Correlation significant at \(p < .05\), two-tailed; \(df = 140\) (mothers), \(df = 124\) (fathers)
Table 7.

Results of regression models of treatment group and family demographic variables on academic achievement

<table>
<thead>
<tr>
<th>Family SES* (n = 163)</th>
<th>Reading^b</th>
<th>Spelling^b</th>
<th>Arithmetic^b</th>
</tr>
</thead>
<tbody>
<tr>
<td>Predictor</td>
<td>β^c</td>
<td>β^d</td>
<td>R</td>
</tr>
<tr>
<td>Step1:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group</td>
<td>- .18</td>
<td>- .18</td>
<td>.26</td>
</tr>
<tr>
<td>Family SES</td>
<td></td>
<td></td>
<td>.19</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>.12</td>
</tr>
<tr>
<td>Step2:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group x</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Family SES</td>
<td>- .05</td>
<td>.26</td>
<td>.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Father’s Education (n = 125)</th>
<th>Reading^b</th>
<th>Spelling^b</th>
<th>Arithmetic^b</th>
</tr>
</thead>
<tbody>
<tr>
<td>Predictor</td>
<td>β^c</td>
<td>β^d</td>
<td>R</td>
</tr>
<tr>
<td>Step 1:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group</td>
<td>- .21</td>
<td>-.31</td>
<td>.23</td>
</tr>
<tr>
<td>Father Educ.</td>
<td>-.11</td>
<td>.09</td>
<td></td>
</tr>
<tr>
<td>Step 2:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group x</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Father Educ.</td>
<td>- .11</td>
<td>.23</td>
<td>.00</td>
</tr>
</tbody>
</table>

63
### Mother’s Education (n = 141)

<table>
<thead>
<tr>
<th>Predictor</th>
<th>Reading</th>
<th></th>
<th></th>
<th></th>
<th>Spelling</th>
<th></th>
<th></th>
<th></th>
<th>Arithmetic</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\beta^c$</td>
<td>$\beta^d$</td>
<td>$R$</td>
<td>$\Delta R^2$</td>
<td>$\Delta F$</td>
<td>$p$</td>
<td>$\beta^c$</td>
<td>$\beta^d$</td>
<td>$R$</td>
<td>$\Delta R^2$</td>
<td>$\Delta F$</td>
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<td>Step 1:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group</td>
<td>-.17</td>
<td>.14</td>
<td>.17</td>
<td>.03</td>
<td>1.83</td>
<td>.17</td>
<td>-.87</td>
<td>-.15</td>
<td>.09</td>
<td>.01</td>
<td>.46</td>
</tr>
<tr>
<td>Mother Educ.</td>
<td>-.01</td>
<td>.04</td>
<td>.00</td>
<td>.01</td>
<td>.04</td>
<td>.63</td>
<td>.03</td>
<td>.04</td>
<td>.20</td>
<td>.04</td>
<td>.02</td>
</tr>
<tr>
<td>Step 2:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group x</td>
<td>-</td>
<td>-.32</td>
<td>.18</td>
<td>.00</td>
<td>.25</td>
<td>.62</td>
<td>-</td>
<td>.07</td>
<td>.09</td>
<td>.00</td>
<td>.01</td>
</tr>
</tbody>
</table>

*SES based on Revised Duncan Scores of occupational prestige; when both parents reported occupations, the higher of the two was used.

*Wide Range Achievement Test—subtest discrepancy scores—based on age referenced standard scores.

*Standardized beta weight for Step 1.

*Standardized beta weight for Step 2.

**Bolded** values indicate $p \leq .05$. 
Table 8.

*Regression models predicting achievement discrepancy scores from the interaction of treatment group and maternal report of family environment (N = 153)*

<table>
<thead>
<tr>
<th><strong>Support</strong>&lt;sup&gt;a&lt;/sup&gt;</th>
<th><strong>Reading</strong>&lt;sup&gt;b&lt;/sup&gt;</th>
<th><strong>Spelling</strong>&lt;sup&gt;b&lt;/sup&gt;</th>
<th><strong>Arithmetic</strong>&lt;sup&gt;b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Predictor</strong></td>
<td><strong>β&lt;sup&gt;c&lt;/sup&gt;</strong></td>
<td><strong>β&lt;sup&gt;d&lt;/sup&gt;</strong></td>
<td><strong>R</strong></td>
</tr>
<tr>
<td>Step 1: Group</td>
<td>-.14</td>
<td>-.14</td>
<td>.30</td>
</tr>
<tr>
<td>Step 2: Group x Support</td>
<td>-</td>
<td>-.12</td>
<td>.26</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Conflict</strong>&lt;sup&gt;a&lt;/sup&gt;</th>
<th><strong>Reading</strong>&lt;sup&gt;b&lt;/sup&gt;</th>
<th><strong>Spelling</strong>&lt;sup&gt;b&lt;/sup&gt;</th>
<th><strong>Arithmetic</strong>&lt;sup&gt;b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Predictor</strong></td>
<td><strong>β&lt;sup&gt;c&lt;/sup&gt;</strong></td>
<td><strong>β&lt;sup&gt;d&lt;/sup&gt;</strong></td>
<td><strong>R</strong></td>
</tr>
<tr>
<td>Step 1: Group</td>
<td>-.13</td>
<td>-.14</td>
<td>.22</td>
</tr>
<tr>
<td>Conflict</td>
<td>.18</td>
<td>.34</td>
<td></td>
</tr>
<tr>
<td>Step 2: Group x Conflict</td>
<td>-</td>
<td>-.23</td>
<td>.27</td>
</tr>
<tr>
<td>Predictor</td>
<td>Reading</td>
<td></td>
<td></td>
</tr>
<tr>
<td>--------------------</td>
<td>---------</td>
<td>------------</td>
<td>------------</td>
</tr>
<tr>
<td></td>
<td>$\beta^c$</td>
<td>$\beta^d$</td>
<td>$R$</td>
</tr>
<tr>
<td>Step 1:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group</td>
<td>-.12</td>
<td>-.13</td>
<td>.20</td>
</tr>
<tr>
<td>Achievement</td>
<td>-.15</td>
<td>-.28</td>
<td></td>
</tr>
<tr>
<td>Step 2:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group x</td>
<td>-</td>
<td>.17</td>
<td>.23</td>
</tr>
<tr>
<td>Achievement</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Family Environment (FES) scales
*Wide Range Achievement Test – subtest discrepancy scores based on age referenced standard scores
*Standardized beta weight for Step 1
*Standardized beta weight for Step 2
**Bolded** values indicate $p \leq .05
Table 9.

Regression models predicting achievement discrepancy scores from the interaction of treatment group and paternal report of family environment (N = 101)

<table>
<thead>
<tr>
<th>Support</th>
<th>Predictor</th>
<th>βc</th>
<th>βd</th>
<th>R</th>
<th>ΔR²</th>
<th>ΔF</th>
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**Achievement Orientation**

**Reading**

**Spelling**

**Arithmetic**

| $^a$Family Environment (FES) scales | $^b$Wide Range Achievement Test–subtest discrepancy scores–based on age referenced standard scores | $^c$Standardized beta weight for Step 1 | $^d$Standardized beta weight for Step 2 | **Bolded** values indicate $p \leq .05$ |
APPENDIX B: Figures
Figure 1.

Schematic representation of treatment, demographic, and family environment characteristics that may influence academic achievement discrepancy scores

- Discrepancy scores are the difference in mean scores between survivors and controls for each academic domain (i.e. Mean Reading_{BTS} - Mean Reading_{CC}).
- SES based on Revised Duncan Scores of occupational prestige; when both parents reported occupations, the higher of the two was used.
- Based on parent-rating on Family Environment Scale (FES).
Figure 2.

Model of demographic or family environment factors moderating academic achievement outcomes

\[\text{Family Demographic Variables}^b\]

\[\text{Treatment Type}^a\]

\[\text{Magnitude of academic achievement discrepancy scores}^c\]

\[\text{Family Environment Variables}^d\]

\[\text{Treatment Type}^a\]

\[\text{Magnitude of academic achievement discrepancy scores}^c\]

\(^a\) Surgery only; adjuvant therapy only; surgery plus adjuvant treatment

\(^b\) Demographic variables (i.e., family SES, parental education level)

\(^c\) Discrepancy scores are the difference in mean scores between survivors and controls for each academic domain (i.e., $\text{Mean Reading}_{\text{BTS}} - \text{Mean Reading}_{\text{CC}}$)

\(^d\) Based on parent-rating on Family Environment Scale (FES) scales: support, conflict, achievement orientation.
Correlation of brain tumor survivor family SES\textsuperscript{a} and WRAT\textsuperscript{b} reading discrepancy scores\textsuperscript{c} between brain tumor survivors and classmate controls

\textsuperscript{a} SES based on Revised Duncan Scores of occupational prestige; when both parents reported occupations, the higher of the two was used.

\textsuperscript{b}Wide Range Achievement Test-WRAT

\textsuperscript{c}Discrepancy scores are the difference in mean scores between survivors and controls for each academic domain (i.e.,\text{Mean Reading}_{\text{BTS}}-\text{Mean Reading}_{\text{CC}})