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Executive Functions and Social Skills in Survivors of Pediatric Brain Tumor

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Abstract

Medical advances have resulted in increased survival rates for children with brain tumors. Consequently, issues related to survivorship have become more critical. The use of multimodal treatment, in particular cranial radiation therapy, has been associated with subsequent cognitive decline. Specifically, deficits in executive functions have been reported in survivors of various types of pediatric brain tumor. Survivors are left with difficulties, particularly in self-monitoring, initiation, inhibition, and planning, to name a few. Another domain in which survivors of pediatric brain tumor have been reported to show difficulty is that of social skills. Parents, teachers, and survivors themselves have reported decreased social functioning following treatment. Deficits in executive functions and social skills are likely interrelated in this population, as executive skills are needed to navigate various aspects of social interaction; however, this has yet to be studied empirically. Twenty-four survivors of pediatric brain tumor were assessed using a computerized task of executive functions, as well as paper and pencil measures of social skills and real world executive skills. Social functioning was related to a specific aspect of executive functions, i.e., the survivors' variability in response time, such that inconsistent responding was associated with better parent-report and survivor-report social skills, independent of intellectual abilities. Additionally, parent-reported real-world global executive abilities predicted parent-reported social skills. The implications of these findings for social skills interventions and future research are discussed.

Keywords

Childhood brain tumor; executive functions; neuropsychology; social skills; cognition

Brain tumor is the second most common type of childhood cancer, accounting for approximately 20% of all diagnoses (Kaatsch, 2010). Brain tumors vary widely according to location, size, and histological composition. The overall incidence of pediatric brain tumor is approximately 4.5 in 100,000 (CBTRUS, 2008); however, various types of tumors peak in incidence at different points in development. The use of multimodal treatment has significantly increased survival rates in the past few decades, and consequently survivorship issues have become increasingly important. The long-term morbidities of treatment (termed

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"late effects") may be severe and include endocrine, neurological, hearing/visual, and especially cognitive dysfunction (Aarsen et al., 2004; Anderson, 2005; Gurney et al., 2003).

Of particular concern is the impact of these treatments on higher-order neurocognitive functioning, particularly executive functions. Executive functions can be conceptualized in four main components, including volition/initiation, planning, purposive action, and effective performance (Lezak, 2004). Executive functions continue to develop throughout childhood and adolescence, and this maturation occurs along with progressive neuronal myelination (i.e., white matter tract formation) in the brain (Anderson, Anderson, Northam, Jacobs, & Catroppa, 2001; Barnea-Goraly et al., 2005; Giedd et al., 1999). The beginnings of executive functions have been studied in infants and toddlers (Marcovitch & Zelazo, 2009), and are widely considered to continue developing into young adulthood (Luna et al., 2001).

Deficits in executive functions have been found in survivors of pediatric brain tumor across ages, diagnoses, and treatment types, in skills such as selective attention, working memory, metacognition, planning, and cognitive flexibility, (Aarsen et al., 2009; Maddrey et al., 2005; Spiegler et al., 2004). While deficits tend to be more deleterious in youth who received cranial radiation therapy (CRT), some difficulties were also noted in those undergoing only surgical resection (Carpentieri et al., 2003; Levisohn, Cronin-Golomb, & Schmahmann, 2000). Conceptual models have integrated the variety of demographic (e.g., gender), developmental, treatment-related, and tumor-related factors that affect intellectual and academic achievement (see Reddick et al., 2003; Palmer, 2008). Supporting these models, neuroimaging research in this population has begun to link deficits in some areas of executive functions (i.e., processing speed and attention) to reduced white matter volume in the relevant neural substrates within the brain (Aukema et al., 2009; Reddick et al., 2003). Additionally, deficits in some areas of executive functions have been linked to lower functional outcomes (e.g., education level and obtaining full-time employment), and poorer self-reported quality of life in survivors of pediatric brain tumor (Ellenburg et al., 2009; Waber et al., 2006).

Similar to executive functions, social skills are a multifaceted construct. We define social skills as a set of abilities necessary for successful interaction, which are one facet of the larger construct of social competence (Cavell, 1990). Relationships between executive functions and social skills have been long studied by such notable researchers as Luria (1961) and Vygotsky (1978), who described the development of executive functions as natural consequences of social learning. Concurrent with myelination and development of executive functions in adolescence, social cognitive processes such as perspective-taking and theory of mind are also thought to mature during adolescence (Blakemore & Choudhury, 2006). These executive processes are learned and maintained through language and social interaction, and thus mature over the lifespan in typically developing individuals. However, more recent longitudinal research has suggested that in fact executive functions may play a precursor role to developing mature social skills (Nigg, Quamma, Greenberg, & Kusche, 1999; Carlson, Mandel, & Williams, 2004).

While the directionality of a causal relationship between executive functions and social skills is yet to be determined, research in both clinical and non-clinical samples has consistently demonstrated a relationship between the two domains of functioning (Janusz, Kirkwood, Yeates & Taylor, 2002; Nigg, et al. 1999; see Riggs, Jahromi, Razza, Dillworth-Bart, & Mueller, 2006 for a review). Executive functions have been implicated as potential moderators, mediators, and outcome measures in interventions to promote social competence (Riggs et al., 2006). In survivors of pediatric brain tumor who received cranial radiation therapy, poorer auditory attention span was implicated as a mediator of the relationship between longer time since treatment and greater difficulties with adaptive functioning (Papazoglou, King, Morris, Morris, & Krawiecki, 2008). Additionally, multiple studies have reported a robust relationship between parent-reported attention problems and parent-reported socialization difficulties (Papazoglou, King, Morris, & Krawiecki, 2009; Patel, Lai-Yates, Anderson, & Katz, 2007). Finally, in another investigation, parent-reported social competence of survivors of pediatric brain tumor was related to body mass index (BMI), such that underweight survivors were perceived as having lower social competence; additionally, underweight status was related to survivors' self-perception of fewer close friendships in the presence of low IQ in this study (Schulte et al., 2010).

Studies of patients with acquired brain injuries have suggested that social problem solving skills mediate the deleterious effects of executive dysfunction on social skills (Janusz et al., 2002). Yeates and colleagues (2007) proposed a heuristic model for social competence in children with brain disorder, in which risk and resilience factors related to the brain insult (e.g., type as well as severity of insult) and not related to the brain insult (e.g., parenting style, socioeconomic status) affect social information processing, social interaction, and social adjustment. Social information processing, a latent variable encompassing social/affective functions, social problem-solving, and cognitive/executive functions, is particularly relevant for our research question, and was posited by Yeates and colleagues to affect social interaction abilities. In a specific brain-injured population, a study in children with the 22q11 deletion syndrome found that parent-report executive function deficits were related to lower parent-reported social skills (Kiley-Brabeck & Sobin, 2006).

Within survivors of pediatric brain tumor, deficits in social skills and increased social problems have been noted (Schulte & Barrera, 2010) and been shown to worsen steadily over time in survivors who received CRT (Mabbott et al., 2005). The learning and social deficits in survivors of pediatric brain tumor have been linked to a nonverbal learning disability profile (Bonner, Hardy, Willard, & Gururangan 2009; Buono et al., 1998; Carey, Barakat, Foley, Gyato, & Phillips, 2001), and survivors of pediatric brain tumor have been noted to have difficulties in recognizing facial expressions (Bonner et al., 2008). Several intervention studies have established the feasibility and small to moderate effects of social skills training programs in survivors of pediatric brain tumor (Barakat et al., 2003; Barrera & Schulte, 2009). Nonetheless, the specific relationships between executive functions and social skills in the pediatric brain tumor population remain unclear.

There are relatively few studies describing and quantifying the social deficits in survivors of pediatric brain tumor, with more research focusing on designing interventions to remediate social deficits. One topic that remains in question is the relationship between executive functions and social skills in this population. The present study investigated social skills and executive functions in survivors of pediatric brain tumor at two urban children's medical centers, with the particular goal of parsing out relationships between various subdomains of executive functions and social skills. We hypothesized that better executive functioning as measured by objective and parent-report measures would be related to higher scores on social skills measures across reporters. Additionally, we aimed to explore whether these relationships could be partially explained by general cognitive ability; we hypothesized that overall cognitive ability would not explain the relationship between executive functions and social skills (as was found in Carey et al., 2001).

Methods

Participants

Survivors of childhood brain tumor were recruited from two urban children's hospitals in the United States. Eligibility criteria included diagnosis of any type of brain tumor, at least six months off treatment, and between the ages of 8–18 years. Exclusion criteria included IQ < 70 and sensory or neurological impairment that precluded them from completing the tasks. Survivors with neurofibromatosis type 1 (NF-1) were excluded from this study. Survivors who received any combination of treatments (i.e., surgery, chemotherapy, and/or radiation therapy) were included. Every participant and parent/guardian completed informed consent and assent (when applicable), and this study was approved by the governing institutional review boards at both universities.

Procedure

Following informed consent each participant's caregiver completed a demographic questionnaire, as well as paper-and-pencil measures of social skills (the Social Skills Information System [SSIS], discussed below) and executive function (the Behavior Rating Inventory of Executive Function, discussed below). Survivors of pediatric brain tumor completed a paper-and-pencil self-report measure of social skills (SSIS), a computerized measure of executive functions (the Tasks of Executive Control [TEC], discussed below), as well as a measure of intellectual functioning (Wechsler Intelligence Scale for Children-Fourth Edition [WISC-IV] or Wechsler Abbreviated Scale of Intelligence [WASI], discussed below).

Measures

Demographic Questionnaire: Caregivers completed a brief demographic questionnaire assessing survivor characteristics including details of treatment, current academic and social functioning, and current accommodations or modifications in school.

Social Skills Information System (SSIS; Gresham & Elliot, 2008): This questionnaire assesses various skills related to successful social functioning (e.g., responsibility, cooperation, etc.). The measure yields an Overall Social Skills composite score, which is standardized by age., and was used in preliminary analyses. Scores for the subscales (i.e., Communication, Cooperation, Assertion, Responsibility, Empathy, Engagement, and Self-Control) were also obtained and used for follow-up analyses. The SSIS is relatively new; however its previous version, the Social Skills Rating System (SSRS), has been extensively used in the literature (e.g., Demaray et al., 1995; Fagan & Fantuzzo, 1999; Diperna & Volpe, 2005). A recent study comparing the SSIS and SSRS determined that the SSIS rating scales had greater internal reliability than the SSRS, though both have excellent psychometric properties (Gresham, Elliott, Vance, & Cook, 2011). Each participant and accompanying caregiver completed the SSIS rating scales.

Behavior Rating Inventory of Executive Function (BRIEF; Gioia, Isquith, Guy, & Kenworthy, 2000): This standardized questionnaire assesses executive functions by rating a child's everyday behavior, and has sound psychometric properties. The BRIEF consists of 86 questions completed by the child's caregiver that contribute to eight executive function domains including Inhibit, Shift, Emotional Control (Behavioral Regulation subscales), Working Memory, Initiate, Monitor, Plan/Organize, and Organization of Materials (Metacognition subscales). The BRIEF also yields an overall Global Executive Composite (GEC) score, which was used in analyses. Higher T-scores, standardized by age, indicate greater dysfunction. Caregivers completed this measure of real life executive function.

Tasks of Executive Control (TEC; Isquith, Roth, & Gioia, 2010): The TEC is a psychometrically sound, standardized, computerized measure that combines traditional neuroscience methods including an n-back paradigm that increases working memory load, and a go/no-go task that manipulates inhibitory control demands. There are three levels of working memory demand presented (0, 1, 2-back), crossed with absence vs. presence of an inhibitory signal. In addition to assessing working memory and inhibitory control functions, vigilance and sustained attention is also assessed. Higher T-scores, standardized by age, indicate greater impairment. Summary scores from the TEC utilized for analyses included Sustained Accuracy (accuracy in responding during the task), Response Speed (speed of responding during the task), and Response Speed Intraindividual Coefficient of Variability (consistency of response speed during the task)

Wechsler IQ Scales. Each participant's IQ was measured using either the Wechsler Abbreviated Scale of Intelligence (WASI; Wechsler, 1999) or the Wechsler Intelligence Scale for Children-Fourth Edition (WISC-IV; Wechsler, 2003). Both the WASI and WISC-IV have excellent reliability and validity in child populations.

Data Analyses

Data were examined to ensure that statistical criteria were met for planned analyses. Initial descriptive data were extricated from the parent-report demographic questionnaire. To address the hypothesis that better scores on executive function measures would be related to higher scores on measures of social skills, we examined preliminary bivariate correlations between SSIS Summary Scores (from both child- and parent-report) and the BRIEF GEC and selected TEC Indices (i.e., Sustained Accuracy, Response Speed, and Response Time Intraindividual Coefficient of Variability [ICV] scores). To evaluate relationships between executive functioning and specific domains of social skills, follow-up bivariate correlations were then obtained between SSIS subscales and empirically-selected executive function indices. Finally, based upon existing literature documenting that IQ may be related to some aspects of both social skills and executive functions (Lewis et al., 2000; Ardila, Pineda, & Rosselli, 2000), in comparison to previous studies finding no relationship to this effect in survivors of pediatric brain tumor (Carey et al., 2001), a regression equation was performed examining whether executive function indices predicted social skills over and above the influence of IQ. Given our relatively small sample size and the number of statistical comparisons performed, significance level was set at $p < 0.01$ in order to offset the chance for making a Type I error.

Results

Participant Descriptive Data

A total of 24 participants, recruited consecutively, consented to participate and met all eligibility criteria. The average age at diagnosis was 9.1 years (*SD* = 3.67; *Range*: 2.0–17.0 years), and participants were on average 4.6 years from completion of treatment at the time of the study (*SD* = 2.75; *Range*: 1.0–11.0 years). Demographics included 20 Caucasian, 1 Latino, and 3 Asian participants. Eleven of the 24 participants (46%) were male. Twenty-three participants received surgical resection, 17 received chemotherapy, 14 received CRT, and 11 received all three treatment modalities. None of our participants had a history of cerebellar cognitive affective syndrome.

In response to two questions on the demographic questionnaire asking "Did your child have learning problems before (after) their brain tumor diagnosis?" 8% of parents reported their child as having learning difficulties prior to their brain tumor diagnosis, compared with 58% having learning problems after diagnosis and treatment. Thirty-eight percent of our participants were receiving special education services or had a 504 plan in school at the time of the study, and 13% had been retained at least one grade. Socially, however, most parents (71%) reported their child to be getting along "very well" with peers, while 21% reported their child was getting along "okay" with peers (8% left this question blank).

Statistical Assumptions

Data were examined for the statistical assumptions necessary to perform the planned analyses. Assumptions of normality, linearity, homoscedasticity, lack of multicollinearity, and absence of univariate and multivariate outliers were all adequately met.

Descriptive Data on Variables of Interest

Descriptive data was obtained on the following variables of primary interest: BRIEF GEC, TEC Sustained Accuracy, TEC Response Speed, TEC Response Time ICV, parent-report SSIS Overall Social Skills Index, survivor-report SSIS Overall Social Skills Index, and IQ (Table 1). While the mean values on each variable were in the average range, scores were variable ranging from the impaired range to the superior range across most variables. Since all the executive function variables are reported in *T*-scores (M=50, SD=10), we used 65 (1.5 SDs above the mean) as the cutoff for reporting clinically significant impairment. Seven participants were considered impaired in general executive functioning according to parent-report on the BRIEF GEC, two were impaired on TEC Sustained Accuracy, three were impaired on TEC Response Speed, and three were impaired on TEC Response Time ICV. Social skills scores were reported as standard scores (M=100, SD=15), so clinically significant impairment was defined as a score of less than 78 (1.5 SDs below the mean). Four participants were classified as impaired according to the parent-report SSIS, and one participant was impaired according to survivor-report SSIS. Pearson correlation coefficients obtained between parent-report and survivor-report Overall Social Skills scores on the SSIS indicated overall agreement between the two perspectives ($r = .53$, $p < 0.01$).

Executive Functions and Overall Social Skills

Initial correlational analyses revealed that the BRIEF GEC score was related to parent-report Overall Social Skills such that worse executive function scores corresponded with poorer social skills ($r = -0.69$; Table 2), although GEC scores were not related to survivor-reported social skills. TEC Response Speed and Sustained Accuracy Indices were not related to social skills summary scores. However, the TEC Response Time ICV was related to both parent-report social skills ($r = -0.67$) and survivor-report social skills ($r = -0.63$) such that lower levels of response consistency were associated with poorer social skills. The TEC Response Time ICV and the BRIEF GEC were retained for further analyses to parse out more specific relationships between executive abilities and certain aspects of social skills.

Executive Functions and Specific Social Skills

Additional correlational analyses were conducted separately for parent-report and child-report social skills. Review of parent-reported social skills data (Table 3) indicated that the TEC Response Time ICV score was related to indices of Communication ($r = -0.70$), Cooperation ($r = -0.65$), Responsibility ($r = -0.61$), Empathy ($r = -0.56$), and Self-Control ($r = -0.56$), all in the direction that greater variability in responding was related to worse functioning in those domains. The TEC Response Time ICV score was not related to the parent-report Assertion or Engagement indices. When examining the parent-report BRIEF and parent-report social skills, the overall GEC score was found to be related to indices of Communication ($r = -0.62$), Cooperation ($r = -0.80$), Responsibility ($r = -0.75$), and Self-Control ($r = -0.58$), such that poorer executive functions were related to worse social abilities in those areas. The BRIEF GEC score was not related to parent-reported indices of Assertion, Engagement, or Empathy.

In examining survivor-report social skills, similar results were found (Table 3). The TEC Response Time ICV score was associated with Communication ($r = -0.55$), Cooperation ($r = -0.64$), Responsibility ($r = -0.73$), Empathy ($r = -0.57$), and Self-Control ($r = -0.52$), such that more variable responding was related to decreased social skill ratings in these areas. Similar to parent-reported social skills, TEC Response Time ICV scores were unrelated to survivor self-reported Assertion or Engagement. The parent-report BRIEF GEC was not related to any indices of survivor-reported social skills.

Executive Functions, Social Skills, and IQ

Our final analyses examined whether intellectual functioning could explain the strong relationships found between TEC Response Time ICV, BRIEF GEC, and parent and survivor-reported social skills. A series of hierarchical multiple regression analysis to predict parent-report Overall Social Skills was performed such that IQ was entered in Step 1, and TEC Response Time ICV was entered in Step 2 (Table 4). Results indicated that a more variable response style predicted poorer parent-reported social skills over and above the variance accounted for by IQ ($\Delta R^2 = .50$). Additionally, as was found with parent-reported social skills, greater response variability predicted worse survivor-reported social skills over and above intellectual abilities ($\Delta R^2 = .38$).

The second set of multiple regression analyses examined whether the BRIEF GEC predicted parent-reported or survivor-reported social skills after accounting for IQ (Table 5). While poorer BRIEF GEC score was found to be a predictor of worse parent-reported social skills after taking into account IQ, it did not predict survivor-reported social skills. Notably, IQ was not a predictor of parent-report or survivor-report social skills in any of these multiple regression analyses, despite the wide ranges of IQ and social skills scores.

In summary, findings indicate that intra-individual variability in response time (TEC Response Time ICV) and global everyday executive functions (BRIEF GEC) are related to parent-report of overall social skills, while only TEC Response Time ICV was related to survivor-report social skills. Poorer executive functioning across measures was associated with specific social skills that require consistency in responding, including communication, cooperation, responsibility, engagement, and self-control. BRIEF GEC and TEC Response Time ICV scores were found to predict parent-report Overall Social Skills, and TEC Response Time ICV to predict survivor-report social skills, after accounting for intelligence. IQ was not related to parent-reported, nor survivor-reported, social skills.

Discussion

The present study sought to explore relationships between executive function and social skills in a heterogenous group of survivors of pediatric brain tumor, a population shown to exhibit deficits in both domains. Previous literature has found associations between executive abilities and social adjustment in typically developing children (Jacobson, Williford, & Pianta, 2011). Conceptually, executive functions such as self-monitoring, inhibition, shifting, and working memory would seem necessary for social tasks such as following social norms, holding a back-and-forth conversation, and maintaining friendships. This is interesting in light of research in autism, for example, which has shown that cognitive shifting is a stronger predictor of social understanding than global intelligence or other neurocognitive abilities (Berger et al., 1993).

In our study, using a computerized assessment tool sensitive to various aspects of executive functions, we found that intra-individual variability in response time was related to parent-report and survivor-report of social skills. Intra-individual response time variability has been implicated as an important variable in attentional regulation disorders (Kelly, Uddin, Biswal, Castellanos & Milham, 2008). It has been recognized as a better indicator of impairments in various clinical groups (e.g., Attention-Deficit/Hyperactivity Disorder [ADHD]) than measures of central tendency such as mean accuracy or reaction time (Klein, Wendling, Huettner, Ruder, & Peper, 2006), and has been linked to parent report of attention and executive functions among youth with ADHD (Gómez-Guerrero et al., 2010). Maintaining a consistent response style, and thus low response time variability, has been linked to functioning of the dorsolateral prefrontal cortex and the integrity of GABA-mediated circuits involving the frontal lobes (Pouget, Wattiez, Rivaud-Pechoux, & Gaymard, 2009). As the frontal lobes are still developing during childhood and adolescence, diagnosis and treatment for a brain tumor during this time may be particularly disruptive to the development of the neural substrates of maintaining low variability in responding, among other executive abilities.

On a conceptual level, maintaining a consistent response style seems particularly relevant for social functioning. Our secondary analyses revealed intra-individual response time variability to relate to specific social skills including communication, cooperation, responsibility, empathy, and self-control in both parent and survivor self-report. Competence in these areas would require consistent interaction and effective self-monitoring in social situations, abilities that are compromised by a highly variable response style. Additionally, intra-individual variability was not related to assertion according to both parent and survivor-report, or to engagement according to parent-report. Assertion and engagement are more time-limited skills, requiring a single action of standing up for oneself or joining in a game, not more continuous abilities such as communicating effectively during a conversation or cooperating with a group.

In addition to variability in response time, parent report of real-world executive function behaviors was also related to particular parent-reported social skills difficulties, including trouble with communication, cooperation, responsibility, and self-control. This provides convergent evidence of executive function abilities in real-world environments (as meaningful correlates of social skills. As performance in the real world does not always align with skills measured during neuropsychological testing, the similarities in relationships noted between BRIEF GEC and TEC Response Time ICV scores with parent-reported social skills suggests that these two global constructs, social skills and executive functions, are related in a meaningful way in survivors of pediatric brain tumor.

Discerning the neurocognitive impairments underlying social skills deficits in survivors of pediatric brain tumor is important on several levels. First, as these children and adolescents tend to be cognizant of their social deficits (Boydell, Stasiulis, Greenberg, Greenberg, & Spiegler, 2008), educating survivors about the reasons for their difficulties is important. In our clinical experience, when survivors of pediatric brain tumor, particularly adolescents or young adults, are informed that their difficulties with attention or processing speed (for example) are not because they are “lazy” or “slow,” but instead are sequelae of their tumor and its treatment, self-esteem and self-efficacy appear to be positively impacted. Secondly, elucidation of the neuropsychological correlates or mechanisms of social deficits in this population lays a foundation for a different approach to intervention techniques. While social skills interventions have been met with success (Barakat et al., 2003; Barrera & Schulte, 2009), their efficacy may be improved by the addition of a cognitive training aspect, similar to that implemented by Butler et al. (2008) or Hardy, Willard & Bonner (2011).

Although our sample size in this study was relatively small and included mixed diagnoses and treatment regimens, it is comparable to that of other studies with this specialized population (e.g., Barakat et al., 2003; Barrera & Schulte, 2009). Certainly these results are preliminary and call for further study and replication. Despite our efforts to utilize several empirically-validated measures of executive functions and social skills, including objective and subjective measures, the use of different modalities may have introduced method variance, potentially affecting our results. In addition, one of the limitations in this line of research is the difficulty in assessing such a multidimensional construct as social skills. We utilized parent-report and survivor-report questionnaires that only peripherally measured social skills in our sample. Hence, future research should include more objective measures of social skills, such as a standardized social problem-solving tasks (e.g., Janusz, 2002), as well as measures from different reporters such as peers and teachers. Additionally, larger sample sizes, more homogenous cohorts, and sibling or typically developing control groups will afford the use of more complex statistical methods, including multilevel modeling, which may be particularly interesting in parsing out the relationships between various aspects of social skills and executive functions. Since this is a cross-sectional study, we cannot assume causality between increased variability in responding or poor parent-reported executive abilities and social skills deficits. A third, not studied, variable may be impacting both factors; for example, depression or anxiety could impact both executive functions and social skills. We attempted to account for one potential factor, intellectual ability, but found that IQ was unrelated to social skills in this sample. This lack of relationship with IQ may have been related to our exclusion of participants with IQ < 70, as they would have had great difficulty with the TEC. Future studies using longitudinal data will be better able to explore the possibility of a causal relationship between executive function deficits caused by a brain tumor and its treatment in childhood, and deficits in social skills in survivorship.

Despite limitations, the current study provides important insights into the relationships between executive functions and social skills in youth with brain tumors. Specifically, we found that a survivor’s ability to maintain consistent responding over a period of time was positively related to better social skills across various domains. This has important implications for future social skills and executive function interventions in this population, as working concurrently to address both areas of difficulty may be more effective than interventions targeting one domain independently of the other.

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Table 1

Descriptive Data on Variables of Interest

Measure	N	Mean	SD	Range	# Impaired[†]
BRIEF GEC[a]	24	57.1	15.62	36–96	7
TEC Sustained Accuracy[a]	24	49.1	11.37	34–88	2
TEC Response Speed[a]	24	48.9	12.64	35–84	3
TEC Response Time ICV[a]	24	51.3	9.70	39–67	3
SSIS Parent-Report Overall Social Skills[b]	24	99.3	15.77	72–126	4
SSIS Survivor-Report Overall Social Skills[b]	24	102.2	15.58	67–128	1
IQ[b]	22	100.5	14.61	75–122	1

Note. SD = Standard Deviation; BRIEF = Behavior Rating Inventory of Executive Function; GEC = Global Executive Composite; TEC = Tasks of Executive Control; ICV = Intraindividual Coefficient of Variability; SSIS = Social Skills Information System; IQ = Intelligence Quotient.

[†] Impairment defined as > 1 SD below the mean

[a] = *T*-Score (mean = 50, SD = 10).

[b] = Standard Score (mean = 100, SD = 15).

Table 2

Correlations between Executive Function and Social Skills Variables

	BRIEF GEC	TEC Sustained Accuracy	TEC Response Speed	TEC Response Time ICV
SSIS Parent Report Social Skills	−.69**	−.36	−.15	−.67***
SSIS Survivor Report Social Skills	−.29	−.35	−.13	−.63**

Note. BRIEF = Behavior Rating Inventory of Executive Function; GEC = Global Executive Composite; TEC = Tasks of Executive Control; ICV = Intraindividual Coefficient of Variability; SSIS = Social Skills Information System.

** $p<.01$.

*** $p<.001$.

Table 3

Correlations between Social Skills Subdomains and Executive Function Variables

SSIS Subscales		TEC Response Time ICV	BRIEF GEC
Communication	Parent-Report	−.70***	−.62**
	Survivor-Report	−.55**	−.17
Cooperation	Parent-Report	−.65***	−.80**
	Survivor-Report	−.64**	−.37
Assertion	Parent-Report	−.28	−.22
	Survivor-Report	−.27	−.20
Responsibility	Parent-Report	−.61***	−.75**
	Survivor-Report	−.73***	−.41
Empathy	Parent-Report	−.56***	−.34
	Survivor-Report	−.57**	−.13
Engagement	Parent-Report	−.34	−.18
	Survivor-Report	−.47	−.19
Self-Control	Parent-Report	−.56***	−.58**
	Survivor-Report	−.52**	−.34

Note. SSIS = Social Skills Information System; TEC = Tasks of Executive Control; ICV = Intraindividual Coefficient of Variability; BRIEF GEC = Behavior Rating Inventory of Executive Function Global Executive Composite.

** $p<.01$.

*** $p<.001$.

Table 4

Hierarchical Multiple Regression Analyses Predicting Social Skills from Intra-Individual Response Time Variability

	Social skills measures			
	Parent-report SSIS		Child-report SSIS	
Predictor	**ΔR^2**	**β**	**ΔR^2**	**β**
Step 1. Full-Scale IQ	.00	−.05	.00	−.05
Step 2. TEC ICV	.50***	−.71	.38**	−.61
Total R^2	.50***		.38**	
n	22		22	

Note. SSIS = Social Skills Information System; IQ= Intelligence Quotient; TEC = Tasks of Executive Control; ICV = Intraindividual Coefficient of Variability.

** p<.01.

*** p<.001.

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Table 5

Hierarchical Multiple Regression Analyses Predicting Social Skills from Parent-Reported Executive Functions

	Social skills measures			
	Parent-report SSIS		Child-report SSIS	
Predictor	ΔR^2	β	ΔR^2	β
Step 1. Full-Scale IQ	.00	.04	.08	.28
Step 2. BRIEF GEC	.45**	−.68	.06	−.25
Total R^2	.45**		.14	
n	22		22	

Note. SSIS = Social Skills Information System; IQ = Intelligence Quotient; BRIEF GEC = Behavior Rating Inventory of Executive Function Global Executive Composite.

** $p<.01$.