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Executive Functions and Social Competence in Young Children 6 Months Following Traumatic Brain Injury

Kalaichelvi Ganesalingam^{1,2}, Keith Owen Yeates^{1,2}, H. Gerry Taylor^{3,4}, Nicolay Chertkoff Walz⁵, Terry Stancin⁶, and Shari Wade⁵

¹ The Research Institute at Nationwide Children's Hospital, Columbus, Ohio

² Department of Pediatrics, The Ohio State University, Columbus, Ohio

³ Department of Pediatrics, Case Western Reserve University

⁴ Rainbow Babies & Children's Hospital, University Hospitals Case Medical Center, Cleveland, Ohio

⁵ Department of Pediatrics, Cincinnati Children's Hospital Medical Center and University of Cincinnati College of Medicine, Cincinnati, Ohio

⁶ Department of Psychiatry, MetroHealth Medical Center, Cleveland, Ohio

Abstract

Objective—This study examined the impact of traumatic brain injury (TBI) in young children on executive functions and social competence, and particularly on the role of executive functions as a predictor of social competence.

Method—Data were drawn from a prospective, longitudinal study. Participants were children aged 3.0 to 6.11 years at time of injury. The initial sample included 23 with severe TBI, 64 with moderate TBI, and 119 with orthopedic injuries (OI). All participants were assessed at 3 and 6 months post injury. Executive functions were assessed using neuropsychological tests (Delayed Alternation task and Shape School) and parent ratings on the Behavior Rating Inventory of Executive Function and Child Behavior Questionnaire. Parents rated children's social competence on the Adaptive Behavior Assessment System, Preschool and Kindergarten Behavior Scales, and Home and Community Social Behavior Scales.

Results—Children with severe TBI displayed more negative outcomes than children with OI on neuropsychological tests and ratings of executive functions, and ratings of social competence (η^2 ranged from 0.03 to 0.11). Neuropsychological tests of executive functions had significant but weak relationships with behavioral ratings of executive functions (ΔR^2 ranged from .06 to .08). Behavioral ratings of executive functions were strongly related to social competence (ΔR^2 ranged from .32 to .42), although shared rater and method variance likely contributed to these associations.

Corresponding author: Keith Owen Yeates, Ph.D., The Research Institute at Nationwide Children's Hospital, Nationwide Children's Hospital, 700 Children's Drive, Columbus, Ohio 43205, Phone: (614) 722 4700, Facsimile: (614) 722 4718, Keith.Yeates@nationwidechildrens.org.

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Conclusions—Severe TBI in young children negatively impacts executive functions and social competence. Executive functions may be an important determinant of social competence following TBI.

Keywords

Traumatic brain injury; Young children; Executive functions; Social competence

INTRODUCTION

Traumatic brain injuries (TBI) annually occur in approximately 160 per 100,000 children below the age of 7 years in the United States (Langlois, Rutland-Brown, & Thomas, 2006). Younger age at injury is a significant predictor of deficits in intellectual functioning, attentional skills, language skills, memory, concept generation, mental flexibility, inhibitory control, and motor skills (Anderson et al., 1997; Anderson, Catroppa, Morse, Haritou, & Rosenfeld, 2005; Ewing-Cobbs et al., Miner, Fletcher, & Levin, 1989; Ewing-Cobbs et al., 1997; Ewing-Cobbs, Prasad, Landry, Kramer, & DeLeon, 2004; Morse et al., 1999; Smidts, Jacobs, & Anderson, 2004). Children aged 2 to 7 years at the time of injury are reported to show deficits in attention, expressive language, and academic achievement in comparison to children injured later in age (Anderson et al., 2005; Ewing-Cobbs & Barnes, 2002; Ewing-Cobbs et al., 1989; 1997; Morse et al., 1999; Verger et al., 2000). Possible explanations for poorer outcomes among younger children include fewer established skills upon sustaining insult, greater susceptibility to diffuse brain insult, abnormalities in neurogenesis, and the greater effect of brain injury on post injury development of skills (Anderson & Moore, 1995; Barnes, Dennis, & Wilkinson, 1999; Dennis, Wilkinson, Koski, & Humphreys, 1995; Ewing-Cobbs et al., 1997; Taylor & Alden, 1997; Wetherington & Hooper, 2006).

Childhood TBI is also associated with deficits in social competence (Yeates et al., 2007). Many definitions of social competence have been proposed. Rubin and Krasnor (1986) Rubin and Krasnor (1992) defined social competence as "...the ability to achieve personal goals in social interaction while simultaneously maintaining positive relationships with others over time and across situations." This definition contains many of the essential components of social competence. It treats social competence as a developmental construct that is both time and context dependent and highlights the "complex goals that persons confront as individuals (satisfying personal goals) and as members of groups (while maintaining positive relationships)" (Yeates et al., 2007). Although the precise nature of social impairments associated with pediatric TBI remains to be elucidated, previous studies have shown that children with severe TBI are less skilled at social problem-solving, display impairments in social-affective functions including pragmatic language, understanding of emotions and appreciation of mental states, and are rated as less socially competent and lonelier than healthy children or children with injuries not involving the brain and that their poor social outcomes persist over time (Anderson et al., 2005; Beauchamp et al., 2009; Dennis, Guger, Roncadin, Barnes, & Schachar, 2001; Yeates et al., 2007). Social competence is, however, a vital aspect of young children's development (Rothbart, 1989; Rothbart & Bates, 1998) and children with early difficulties in social behaviors are at increased risk for a range of long-term negative outcomes, including academic failure, peer rejection, and delinquent behavior (Caspi & Moffitt, 1995; Coie & Dodge, 1998).

Social competence is associated with attentional and emotion-related behavioral control (Cicchetti & Tucker, 1994; Eisenberg et al., 2000; Shield & Cicchetti, 1998). Externalizing behavioral problems, for instance, are reported to reflect inadequate regulation or control of attention and impulses (Barkley, 1997; Moffitt, 2003; Olson, Schilling, & Bates, 1999). Studies show that young children with aggressive behaviors exhibit impairments in

inhibition of prepotent responses (Hughes, 1998), deficits in planning and inhibitory control (Hughes, White, Sharpen, & Dunn, 2000), and impaired attention and working memory (Speltz, DeKlyen, Calderon, Greenberg, & Fisher, 1999). Regulation or executive control is thus an important predictor of social competence (McEvoy, Rogers, & Pennington, 1993; Warschausky, Giacoletti, Horvitz, & Berg, 2003). The social deficits exhibited by young children with TBI may reflect compromised executive functions.

Executive functions refers to a set of higher-order regulatory capacities including attentional control, inhibition, working memory, goal setting, planning, problem solving, mental flexibility, and abstract reasoning (Senn, Espy, & Kaufmann, 2004; Welsh, Pennington, & Groisser, 1991) that enable goal-directed behavior (Levin & Hanten, 2005; Lezak, 2004). A significant TBI during early childhood may disrupt executive functions including attention (Willmott, Anderson, & Anderson, 2000), inhibitory control and working memory (Ewing-Cobbs et al., 2004; Nadebaum, Anderson, & Catroppa, 2007; Roncadin, Guger, Archibald, Barnes, & Dennis, 2004), and concept generation and mental flexibility (Smidts et al., 2004). Recent conceptual models of social competence place executive functions in a central role (Beauchamp & Anderson, 2010; Eisenberg et al., 2000; Olson, Sameroff, Kerr, Lopez, & Wellman, 2005; Yeates et al., 2007). Executive control of attention and emotion-related behaviors, for instance, has been linked to prosocial behaviors and positive peer relations among young children (Eisenberg et al., 1997; Zahn-Waxlet, Duggal, & Gruber, 2002), while poor impulse control has been related to externalizing behaviors (Eisenberg et al., 1997; Olson et al., 2005). Deficits in executive and regulatory functions are often associated with abnormalities in the prefrontal regions (Jacobs, Harvey, & Anderson, 2006) and damage to those regions occurs commonly following TBI (Bigler, 2001; Wilde et al., 2005). The role of executive and regulatory functions in social competence following TBI has been examined among school-age children (Ganesalingam, Sanson, Anderson & Yeates, 2007), as well as among adolescents and young adults (e.g., Muscara, Catroppa & Anderson, 2008); however, these relationships have not yet been investigated among young children.

Executive functions are typically assessed using performance-based neuropsychological tests (Gerstadt, Hong, & Diamond, 1994; Zelazo, Frye, & Rapus, 1996). However, the ecological validity of such tests has been questioned by many researchers, because the tests are highly structured, administered in a distraction-free environment, and in some instances provide cues on how to respond (Dennis et al., 2001; Fletcher, Ewing-Cobbs, Miner, Levin, & Eisenberg, 1990; Goldberg & Podell, 2000; Silver, 2000). The test demands are thus argued to be different to that of the child's natural environment, which is often less structured and filled with distractions. An alternative approach to assessing executive functions is to obtain parent ratings of children's everyday behaviors that reflect executive functions (Gioia, Isquith, Gut, & Kenworthy, 2000). The two measurement approaches may be complementary; that is, whereas neuropsychological tests assess specific cognitive components of executive functions at a more molecular level, ratings of behavioral indicators of executive functions assess broader components at a more molar level in everyday contexts (Isquith, Crawford, Espy, & Gioia, 2005). The use of both neuropsychological tests and behavioral ratings may provide a more comprehensive understanding of children's executive functions. The relationship between neuropsychological tests and behavioral ratings tends to be relatively weak among school-age children (Mangeot, Armstrong, Colvin, Yeates, & Taylor, 2002). Although similarly weak relations have been demonstrated among young children (Mahone et al., 2004), these relations have not yet been examined empirically in young children with TBI.

The overall goals of this study were to examine the impact of TBI on executive functions and social competence in young children, and to determine the contribution of executive functions to the prediction of social competence. The specific aim was to examine the

relationship among neuropsychological tests and behavioral ratings of executive functions. We used data drawn from a longitudinal prospective study that included 3.0 to 6.11 year old children with moderate or severe TBI, and a comparison group of same age children with orthopedic injuries (OI) not involving the head. Initial assessments were completed within 3 months of the injury and follow-up assessments occurred at 6 months post injury. Executive functions were assessed using neuropsychological tests and parent ratings. Parents also provided ratings of children's social competence. We hypothesized that neuropsychological tests completed at 6 months would be related to behavioral ratings of executive functions at 6 months and that the measures of executive functions would predict social competence at 6 months post injury. We also hypothesized that young children with TBI would display poorer executive functions and social competence than children with OI not involving the head.

METHODS

Study Design and Procedures

Data were collected as part of a larger prospective, longitudinal study that included young children with moderate or severe TBI and OI not involving the head (Taylor et al., 2008). Participants were recruited from consecutive inpatient admissions at four hospitals. The study was approved by the ethics boards of all participating hospitals and informed consent was obtained before participation. The OI group was included to compare the effects of TBI to traumatic injuries in general and to control for premorbid factors associated with accidental injury as well as the experience of hospitalization. Participating children and their primary caregiver (usually the mother) completed an initial assessment within 3 months post injury and a second assessment 6 months following the initial assessment. On both occasions, children completed cognitive tests of executive functions, while parents rated children's executive functions and social competence. Parent ratings at the initial assessment were intended to reflect children's premorbid functioning.

The majority of assessments (over 95%) were conducted at the participating hospitals (i.e., Nationwide Children's Hospital, Columbus; Rainbow Babies and Children's Hospital, Cleveland; and Cincinnati Children's Hospital, Cincinnati, Ohio); a small number were conducted in the participants' home upon their request. Children required up to 2 hours to complete a battery of cognitive tests that included the measures of executive functions noted in this paper. The children's parents completed a number of questionnaires, including but not limited to those reported in this paper. The completion of the questionnaires required about 2 hours.

Participants

Young children with TBI or OI were recruited from consecutive inpatient admissions from 2003 to 2006 at three tertiary care children's hospitals and a general hospital, in central and northern Ohio, all of which had Level 1 trauma centers. Eligibility criteria for both groups (TBI and OI) included age at injury between 3 years, 0 months and 6 years, 11 months; no documentation in the medical chart or in parent interview of child abuse as a cause of injury; no previous history of autism, mental retardation, or neurological disorder; and English as the primary spoken language in the home.

Eligibility for the TBI group included a blunt trauma requiring overnight hospital admission and either a Glasgow Coma Scale (GCS; Teasdale & Jennett, 1974) score less than 13 or evidence for TBI-related brain abnormalities on acute neuroimaging. Consistent with previous investigations (e.g., Fletcher et al., 1990; Taylor et al., 1999), severe TBI was defined as one resulting in a GCS score of 8 or less. Moderate TBI was defined as a GCS

score of 9 to 12 or a higher GCS score with abnormal neuroimaging. Inclusion in the OI group required a documented bone fracture in an area of the body other than the head that required an overnight hospital stay, without any evidence of loss of consciousness or other findings suggestive of TBI.

A total of 206 children (23 with severe TBI, 64 with moderate TBI, and 119 with OI) were recruited for the larger study. Recruitment rates for families who were contacted were somewhat higher for the TBI group as a whole than for the OI group (53% vs. 35%). However, participants and non-participants did not differ on age at injury, sex, race, or census-based estimates of neighborhood income. The most common reasons for refusal were lack of time (i.e., considerable travel time to participating hospitals and lengthy assessment sessions) and lack of interest.

Table 1 summarizes the characteristics of the participants with severe TBI, moderate TBI and OI. The three groups did not differ in age at injury, gender or race; however, the OI group had a higher SES than the severe TBI group. Additionally, the interval between injury and the initial assessment was shorter for the OI group than for the severe TBI group. This difference likely reflected our willingness to extend recruitment somewhat beyond the desired window (i.e., 3 months post injury) so as to maximize enrollment of children with TBI. Lastly, the lowest GCS score was significantly lower among children with severe TBI than those with moderate TBI.

Attrition and Missing Data

Of the 206 children, 89 (7 with severe TBI, 25 with moderate TBI, and 57 with OI) had data for all measures used in this study at both occasions, while 117 children (16 with severe TBI, 39 with moderate TBI, and 62 with OI) had missing data on one or more measures on at least one occasion. Data was missing due to (i) families not returning for the follow-up assessment at 6 months; (ii) parents not completing or returning rating scales; and (iii) children being unable to complete all neuropsychological tests. Children with missing data on one or more variables did not differ from children without missing data in terms of race, sex, and the number of days before initial assessment. Among children with TBI, those with and without missing data did not differ on their mean GCS score. However, children with missing data were significantly younger at the time of injury than those without missing data. This difference was especially apparent on cognitive tests of executive functions, because younger children were less able to complete some of the more challenging tasks. Moreover, children with missing data were of significantly lower mean SES than those with no missing data. In terms of acute outcomes, children with missing data performed more poorly on one neuropsychological test of executive functions and were rated by parents to have poorer executive functions than those without missing data. To maximize statistical power, we elected to use the maximum number of children available for each data analysis, which varied from 132 to 179 in group comparisons of executive functions and social competence and from 116 to 161 in regression analyses examining the relationship between these outcomes. However, we repeated all analyses using only the 89 children with complete data, and obtained essentially the same results.

Measures

Cognitive tests of executive functions—Cognitive tests of executive functions included the Delayed Alternation task (Espy, Kaufmann, McDiarmid, & Glisky, 1999) and the Shape School (Espy, 1997). In Delayed Alternation, the child is asked to retrieve a reward (e.g., an M&M or a Cheerio) hidden under one of two cups placed side by side. The contingency is then reversed with the reward hidden under the other cup. The child is not allowed to see where the reward is placed, but can learn to anticipate placement because

placement side is reversed after each correct response. Performance was defined in terms of number of consecutively correct alternations. In this study, a maximum of 16 trials were administered. The task was discontinued if participants lifted both cups at the same time. Further, the task was considered complete if participants correctly completed nine consecutive trials. The number of correct alternations was used in the current analyses. The Delayed Alternation task has demonstrated satisfactory reliability and validity (Espy et al., 1999).

The Shape School is a Stroop-like measure of self-regulatory abilities in young children (Espy, 1997; Espy, Kaufmann, Glisky, & McDiarmid, 2001; Nigg, 2000). In this task, the child is first taught to name cartoon “pupils” by their shapes or colors. The child is then asked to name the color of some pupils but not others. This test measures the ability to inhibit prepotent responses and the mental flexibility to switch between color and shape names according to learned rules. Conditions include Simple Naming, Inhibition, Switching, and Both (the latter referring to a condition in which both inhibition and switching are required). An efficiency score was computed for each condition by dividing the number correct by completion time. The efficiency score for each condition was used in the current analysis. The Shape School has demonstrated satisfactory reliability and validity in previous research (Espy et al., 1999; Espy, Bull, Martin, & Stroup, 2006).

Ratings of children’s executive functions—Parents provided ratings of children’s executive functions using the Behavior Rating Inventory for Executive Function (BRIEF; Gioia et al., 2000) and the Child Behavior Questionnaire (CBQ; Ahadhi & Rothbart, 1994). The BRIEF is a standardized rating scale on which parents report the frequency of occurrence of behaviors that reflect executive functions. Because we assessed young children between the ages of 3.0 and 6.11, we used both the preschool and school-age versions of the BRIEF. We used *T*-scores on the General Executive Composite (GEC) scale of the BRIEF as the primary measure, with higher scores representing worse executive functions. The BRIEF has demonstrated satisfactory reliability and validity (Gioia & Isquith, 2004). On the CBQ, parents rate the temperamental characteristics of their child (Olson et al., 2005). An Effortful Control Index was computed by summing scores on the Inhibition Control and Attentional Focusing scales, the two most theoretically and empirically salient components of the effortful control construct (Olson et al., 2005; Rothbart & Bates 1998; Posner & Rothbart, 2000). Higher scores on the Effortful Control Index indicate better executive functions. The CBQ has demonstrated satisfactory reliability and validity in previous research (Rothbart & Bates, 1998).

Ratings of children’s social competence—Social competence was assessed using the Adaptive Behavior Assessment System (ABAS; Harrison & Oakland, 2003). The ABAS assesses children’s ability to communicate and behave appropriately in social interactions. Standardized scores on the Social scale were used in the current study. Higher scores represent better social competence. Social competence was also assessed using the Preschool and Kindergarten Behavior Scales-Second Edition (PKBS-2; Merrell, 1995) and the Home and Community Social Behavior Scales (HCSBS; Merrell & Caldarella, 2000). The PKBS and HCSBS are companion scales that capture social behaviors among young children. In the current study, the PKBS was administered to parents for children aged 3.0 to 5.11 years and the HCSBS was administered for children aged 6.0 and older. For this study, we used the social competence composite from each measure. To enable comparisons across measures, the corresponding summary scores from each measure were transformed to *z* scores (i.e., those from the PKBS-2 for children 3 to 5 years and those from the HCSBS for children 6 years and older). Higher scores represent social competence. The two sets of *z*-scores demonstrated correlations across time that were largely similar in magnitude to the correlations for repeated administrations of the same measure, supporting the assumption

that they provide equivalent measures of social competence. In the OI group, correlations for repeated administrations of the PKBS ranged from .55 to .73, correlations for repeated administrations of the HCSBS ranged from .49 to .68, and correlations between the PKBS and HCSBS over time ranged from .50 to .87. In the TBI group, correlations for repeated administrations of the PKBS ranged from .60 to .76, correlations for repeated administrations of the HCSBS ranged from .75 to .86, and correlations between the PKBS and HCSBS over time ranged from .17 to .91. The PKBS-2 and HCSBS have demonstrated satisfactory reliability and validity (Canivez & Rains, 2002; Merrell, 1995).

Data Analyses

Group comparisons on measures of neuropsychological tests of executive functions were examined across the first 6 months post injury using multivariate repeated-measures analyses of covariance (ANCOVA) with group and assessment (i.e., initial assessment and 6 months post injury) as independent variables. Assessment was a within-subject variable. Dependent variables included the number of correct alternations on the Delayed Alternation task and the efficiency score (i.e., number correct/completion time) on each Shape School condition (Naming, Inhibition, Switching, and Both Inhibition and Switching). Because raw scores on the Delayed Alternation and Shape School were used, age at injury was also included as a covariate in analyses of the cognitive measures.

Group comparisons on behavioral ratings of executive function and social competence were only examined at 6 months post injury using analyses of covariance (ANCOVA), with group as the independent variable. Dependent variables included T-scores on the General Executive Composite scale of the BRIEF, z-scores on the effortful control index of the CBQ and the PKBS/HCSBS social competence composite, and standardized scores on the social scale of the ABAS. To control for socioeconomic status (SES), a composite measure reflecting median census tract income and parent education was included as a covariate in the analyses. Planned contrasts were conducted to compare each of the TBI groups (i.e., moderate and severe TBI) to the OI group. For all group comparisons, effect sizes were assessed using η^2 for overall group differences and Cohen's d for planned contrasts. In all analyses involving group comparisons, which had ns of 132 to 179, statistical power was adequate (.80) to detect at least a medium effect size (i.e., η^2 of .06).

Next, hierarchical regression analyses were conducted to examine the concurrent relations among neuropsychological tests of executive functions, behavioral ratings of executive functions, and social competence at 6 months post injury. Parent ratings of executive functions at the initial assessment were intended to reflect premorbid functioning and therefore only 6 month data were used to predict outcomes. Although neuropsychological tests of executive functions were available at both the initial and 6 months follow-up assessments, results of regression analyses using data from both occasions were essentially the same. Only the results of the regression using the 6 month data are presented.

In the first set of regression analyses, we examined the contribution of the neuropsychological tests of executive functions to the prediction of behavioral ratings of executive functions and social competence. In the first step, SES and age were entered as predictors. Next, group membership (i.e., dummy variables coded to indicate moderate TBI vs. OI and severe TBI vs. OI) was entered in the analysis. Finally, neuropsychological tests of executive functions (i.e., Delayed Alternation and Shape School) were entered collectively as predictors of (a) behavioral ratings of executive functions and (b) social competence. In these analyses, which had ns of 116 to 123, statistical power was adequate to detect a change in R^2 of .07 attributable to the five variables representing executive functions or of .06 for any single independent variable controlling for all others. Hierarchical regression analyses were also conducted to examine the contributions of behavioral ratings

of executive functions to the prediction of social competence. In the first step, SES was entered. Group membership (i.e., dummy variables) was entered in the second step. Lastly, behavioral ratings of executive functions (i.e., BRIEF and CBQ) were entered collectively. In these analyses, which had *ns* of 160 or 161, statistical power was adequate to detect a change in R^2 of .06 attributable to the two variables representing executive functions or of .04 for any single independent variable controlling for all others.

RESULTS

Group Comparisons on Executive Functions and Social Competence

Group comparisons on neuropsychological tests of executive functions are summarized in Table 2. After controlling for age and SES, the main effect of group was significant for the Shape School Switch and Both conditions $F(2, 132) = 7.80, p = .05$ and $F(2, 127) = 5.73, p = .04$. Planned contrasts showed that the severe TBI group performed more poorly than the OI group on the Shape School Switch condition ($d = 5.51, p = .05$) and Shape School Both condition ($d = 4.64, p = .04$). Neither the overall main effect of group nor the planned contrasts were significant for the Delayed Alternation task or the Control and Inhibit conditions of the Shape School. These results are similar to those reported previously for these measures (e.g., Gerrard-Morris et al., 2009; Taylor et al., 2008). Age at injury and SES were both significantly related to cognitive tests of executive functions with younger children and those of lower SES performing more poorly than older children and those of higher SES. No group $\times$ time interactions were significant for any of the neuropsychological tests.

Group comparisons on behavioral ratings of executive functions and the social competence composite at 6 months post injury are also summarized in Table 2. The main effect of group was significant for behavioral ratings of executive functions: BRIEF GEC, $F(2, 160) = 6.30, p = .001$ and CBQ $F(2, 159) = 5.94, p = .001$. In each case, greater deficits were reported for the severe TBI than OI group for the BRIEF GEC ($d = 5.07, p = .001$) and CBQ ($d = 4.77, p = .02$). Further, the main effect of group was significant for ratings of social competence, ABAS $F(2, 158) = 4.17, p = .02$, with greater deficits reported for the severe TBI group than the OI group ($d = 3.34, p = .02$). The overall group difference was not significant for the PKBS/HCSBS, $F(2, 167) = 2.70, p = .07$, however, greater deficits were reported for the severe TBI group than the OI group ($d = 0.18, p = .05$).

Relationship among Executive Functions and Social Competence

The hierarchical regression analyses involving neuropsychological tests as predictors of behavioral ratings of executive functions and social competence are summarized in Tables 3 and 4, respectively. Collectively, SES and age at injury accounted for significant variance in behavioral ratings of executive functions (BRIEF GEC and CBQ) but only SES accounted for significant unique variance such that lower SES was related to greater deficits in executive functions. After controlling for SES and age, group membership (severe vs. OI) accounted for significant incremental variance in only the BRIEF GEC with children, with severe TBI rated as having more executive deficits than their peers with OI. Neuropsychological tests of executive functions did not collectively account for significant incremental variance in behavioral ratings of executive functions after controlling for SES, age, and group membership, both $F(5, 106) < 1.80, p > .05$. However, the Shape School Switch condition predicted significant unique variance in the BRIEF ($t = -2.62, p = .01$), with poorer performance on the Switch condition associated with higher deficits on the BRIEF GEC. In addition, the Shape School Switch and Both conditions each predicted significant unique variance in the CBQ ($t = 2.69, p = .01$ and $t = 2.54, p = .01$), respectively, with poorer performance on both conditions predicting poorer effortful control on the CBQ.

As shown in Table 4, SES and age at injury collectively accounted for significant variance in measures of social competence (ABAS and PKBS/HCSBS), but only SES accounted for significant unique variance, with higher SES related to better social competence. After controlling for SES and age, group membership did not account for significant incremental variance in social competence; however, the contrast of the severe TBI and OI groups predicted significant unique variance in the PKBS/HCSBS, with children with severe TBI rated as having less social competence. Neuropsychological tests of executive functions did not account for significant incremental variance in measures of social competence, after controlling for SES, age, and group membership.

Analyses involving behavioral ratings of executive functions (BRIEF GEC and CBQ) as predictors of social competence are summarized in Table 5. SES and age predicted significant variance in the PKBS/HCSBS composite, but only SES accounted for significant unique variance. SES and age did not collectively predict significant variance in the ABAS, however, SES accounted for significant unique variance, with higher SES relating to greater social competence. In the subsequent step, group membership accounted for significant incremental variance in both the ABAS and PKBS/HCSBS; in both instances, children with severe TBI were rated to have poorer social competence. Behavioral ratings of executive functions collectively accounted for significant variance in measures of social competence, after controlling for SES, age and group membership (see Table 5). Parent ratings on the BRIEF GEC accounted for significant unique variance in the ABAS ($t = -2.88, p = .005$) and PKBS/HCSBS ($t = -5.61, p = .000$), with greater deficits on the BRIEF GEC predicting poorer social competence. Further, the CBQ predicted significant unique variance in the ABAS ($t = 3.72, p = .01$) and PKBS/HCSBS ($t = 3.07, p = .003$) with higher levels of effortful control related to greater social competence.

DISCUSSION

Consistent with previous studies that have demonstrated modest but significant relationships between neuropsychological or cognitive tests and questionnaire ratings of executive functions (Anderson et al., 2006; Mangeot et al., 2002; Mahone et al., 2004), the current study found that certain neuropsychological tests of executive functions accounted for significant unique variance in behavioral ratings of executive functions and effortful control at 6 months, over and above SES, age at injury, and group membership. Specifically, poorer performance on neuropsychological tests of complex executive functions involving mental flexibility (i.e., Shape School Switch and Both conditions) were related to higher behavioral ratings of executive dysfunction and lower ratings of effortful control. These results suggest that deficits in executive functions following severe TBI may partially underlie behavioral impairments indicative of poor self-regulation, metacognition, and effortful control.

In contrast, children's performance on neuropsychological tests of executive functions involving the ability to anticipate contingency reversal and inhibition of a prepotent response (i.e., Delayed Alternation task and Shape School Inhibition condition) did not account for unique variance in behavioral ratings of executive functions and effortful control. This result is consistent with previous studies (e.g., Riccio, Hall, Morgan, Hyde, & Gonzalez, 1994), and suggests that neuropsychological tests of executive functions may sometimes lack ecological validity, in that, they are not sensitive to behavioral aspects of executive functions in the everyday context. The findings imply that children could perform well on tests of executive functions in a highly structured experimental setting yet exhibit difficulties in everyday behavioral aspects of executive functions (Vriezen, Pigott, & Pelletier, 2001; Vriezen & Pigott, 2002). More specifically, because neuropsychological tests often assess the ability to engage in momentary executive activities that are devoid of social context, children's competent performance on such tests may not necessarily reflect

their general inability to perform these skills in the everyday context to achieve social goals over extended periods of time. Nonetheless, the significant relationships demonstrated in the current study between neuropsychological tests involving mental flexibility and the parent ratings of executive functions and effortful control suggests that convergence across neuropsychological tests and behavioral ratings of executive functions is possible.

Neuropsychological tests of executive functions did not account for significant variance in ratings of children's social competence, but this was not entirely unexpected. Previous studies have found only weak relations among laboratory based tests of executive functions and ratings of social competence (Olson et al., 2005). The absence of significant relationships in the current study may be attributable in part to the amount of missing data on neuropsychological tests. The youngest children were often unable to complete the most complex neuropsychological tests, such as the Shape School, resulting in considerable missing data. Moreover, the sample size of the TBI groups was small. The severe TBI group, for instance, consisted of 23 children, only 7 of whom had data on all measures used in this study; many of them were missing data on the neuropsychological tests. Larger samples with less missing data would increase statistical power for detecting effects.

On the other hand, behavioral ratings of executive functions accounted for significant unique variance in social competence at 6 months. Higher levels of behavioral aspects of executive functions were related to higher levels of social competence. These results suggest that reduced social competence following TBI may be linked to deficits in the behavioral expression of executive functions, as suggested in previous research (Yeates et al., 2007). However, these relationships are confounded in part by shared rater and method variance, because parents rated both executive functions and social competence. This limitation could be rectified in future research by obtaining ratings of executive functions and social competence from other sources (e.g., teacher ratings).

In keeping with previous research, we examined the effects of TBI on executive functions and social competence among young children. Consistent with earlier publications from this study (Gerrard-Morris et al., 2009; Taylor et al., 2008; Yeates, Taylor, Walz, Stancin, & Wade, 2010), children with severe TBI performed more poorly than children with OI on neuropsychological tests and behavioral ratings of executive functions as well as social competence (Anderson et al., 1997; Ewing-Cobbs et al., 2004; Prasad, Ewing-Cobbs, Swank, & Kramer, 2002). Specifically, in comparison to children with OI, those with severe TBI demonstrated reduced ability to simultaneously inhibit and switch prepotent responses and were rated by parents to have elevated levels of everyday executive deficits and reduced effortful control. Further, in comparison to children with OI, those with severe TBI demonstrated poorer parent ratings of social competence, suggesting they are less able to communicate and behave appropriately in social interactions. Children with moderate TBI did not perform more poorly than those with OI on measures of executive functions or social competence, suggesting that children with moderate TBI have less pronounced deficits than those with severe TBI, again consistent with previous research (Anderson et al., 1997; 2005; Ewing-Cobbs et al., 1997; 2004; Prasad et al. 2002).

The limited sample size in the severe TBI group, missing data, and shared rater and method variance in the current study are problematic, and therefore the results need to be interpreted with caution. Another limitation in the current study relates to the use of the BRIEF to examine executive functions. Some evidence suggests the BRIEF is less closely related to cognitive tests or performance based measures of executive functions and more closely correlated to ratings of behavior problems and functional impairment (McAuley et al., 2010). Thus, ratings on the BRIEF may reflect behavioral difficulties more than executive deficits in the everyday/home context. This may further account for the strong relationship

between the BRIEF and the measures of social competence (i.e., ABAS and PKBS/HCSBS). The study is further limited by the use of global measures of social competence. Recent comprehensive models of social competence (e.g., Beauchamp & Anderson, 2010; Yeates et al., 2007) may inform future research in the selection of more precise outcome measures based on the specific developmental risks associated with TBI.

Despite these limitations, the findings add to our knowledge regarding the impact of moderate to severe TBI in young children on executive functions and social competence, as well as the relationships among these outcomes. The results suggest that severe TBI is associated with significant deficits in executive functions and social competence at 6 months post injury, but that moderate TBI has less pronounced effects. Further, the results indicate that deficits in executive behaviors, as assessed by parent ratings, predict reduced social competence. The latter finding has important clinical implications. Young children with TBI, in particular severe TBI, should be assessed for deficits in executive functions, because such deficits may in turn contribute to impaired social competence. The current findings encourage future intervention research that considers restoring executive functions as a potential means of fostering social competence among young children following severe TBI.

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Table 1

Sample demographic characteristics

	Group			
	Severe TBI (n = 23)	Moderate TBI (n = 64)	OI (n = 119)	
Age at injury (in years), M (SD)	5.09 (1.03)	5.19 (1.20)	5.12 (1.07)	
Gender (males), n (%)	16 (69.6)	37 (57.8)	69 (58.0)	
Race (Whites), n (%)	16 (69.6)	42 (65.6)	90 (75.6)	
Socioeconomic status ^I , M (SD) *	-0.47 (0.65)	-0.12 (1.10)	0.17 (0.95)	
Lowest GCS score, M (SD) *	3.83 (1.70)	13.45 (2.00)	NA	
Time since injury to baseline assessment (days), M (SD) *	47.35 (23.50)	46.31 (23.50)	35.18 (15.01)	

*
p < .05

^I Socioeconomic status is a composite score that reflects the sample z-score for census tract income combined with the sample z-score for parent education at baseline.

Note. OI = Orthopedic Injury; TBI = Traumatic Brain Injury; GCS = Glasgow Coma Scale, NA = not applicable

Analyses of Group Differences on Neuropsychological Tests and Parent Ratings of Executive Functions and Social Competence 6 months post injury

Table 2

	n	OI M (SE)	Moderate TBI M (SE)	Severe TBI M (SE)	Group F-value ²	Age F-value	SES F-value	Group η^2
<i>Neuropsychological tests of executive functions¹</i>								
Delayed Alternation Task	179	8.21 (0.47)	7.62 (0.63)	5.66 (1.05)	2.48	12.28*	2.48	0.03
Shape School Control condition	169	0.92 (0.04)	0.94 (0.06)	0.76 (0.10)	1.33	31.70*	1.46	0.02
Shape School Inhibit condition	162	1.00 (0.05)	1.00 (0.07)	0.78 (0.12)	1.48	49.95*	8.80*	0.02
Shape School Switch condition	137	0.48 (0.02)	0.44 (0.03)	0.27 (0.05)	7.80*	62.88*	10.14*	0.11
Shape School Both condition	132	0.56 (0.03)	0.57 (0.04)	0.34 (0.06)	5.73*	33.99*	12.10*	0.08
<i>Ratings of executive function³</i>								
BRIEF GEC	164	49.60 (1.35)	52.47 (1.81)	61.60 (3.06)	6.33*	NA	5.07*	0.07
CBQ	163	4.95 (0.09)	4.73 (0.12)	4.18 (0.21)	5.94*	NA	5.83*	0.07
<i>Ratings of social competence⁴</i>								
ABAS Social Scale	162	20.56 (0.60)	21.62 (0.81)	16.96 (1.40)	4.17*	NA	2.00	0.05
PKBS/HCSBS Social Skills Scale	171	0.29 (0.09)	0.15 (0.12)	-0.26 (0.22)	2.70 [†]	NA	9.50*	0.03

* $p < .05$ [†] Planned contrast of severe TBI and OI group significant, $p < .05$.

Marginal means and standard errors estimated in full model, which included injury type (OI, Moderate TBI, Severe TBI) and time as independent variables with age and SES as covariates for cognitive tests of executive functions and only SES as covariate for parent ratings of executive functions.

¹ Analyzed using multivariate repeated-measures (ANCOVA).² F for group comparison on neuropsychological tests was derived from multivariate repeated measures test of between-subjects effects³⁻⁴ Analysed using ANCOVA.NOTE: OI = Orthopedic injury; TBI = traumatic brain injury; η^2 = Partial eta squared (proportion of variance explained) for group effect; BRIEF GEC = Behavior Rating Inventory of Executive Functions General Executive Composite; CBQ = Child Behavior Questionnaire; ABAS = Adaptive Behavior Assessment System; PKBS = Preschool and Kindergarten Behavior Scales, HCSBS = Home and Community Social Behavior Scales.

Table 3

Summary of hierarchical regression analyses predicting parent ratings of executive functions from neuropsychological tests of executive functions at 6-months

<i>n</i>	Dependent Variables	
	BRIEF	CBQ
	116	116
Predictors		
STEP 1 β		
SES	-.34*	.33*
Age	-.09	.16
Total R^2 for Step 1	.11*	.11*
STEP 2 β		
SES	-.26*	.29*
Age	-.08	.15
Moderate TBI vs. OI	.11	-.15
Severe TBI vs. OI	.26*	-.16
ΔR^2 for Step 2	.06*	.04
STEP 3 β		
SES	-.23*	.27*
Age	.05	.09
Moderate TBI vs. OI	.09	-.12
Severe TBI vs. OI	.24*	-.18
Delayed Alternation Task	-.04	.01
Shape School Control	-.03	-.08
Shape School Inhibit	-.03	.07
Shape School Switch	-.34*	.35*
Shape School Both	.20	.30*
ΔR^2 for Step 3	.06	.08

Table 4

Summary of hierarchical regression analyses predicting social competence from neuropsychological tests of executive functions

<i>n</i>	Dependent Variable	
	ABAS	PKBS/HCSBS
	116	123
Predictors		
STEP 1 β		
SES	.24*	.34*
Age	.16	.13
Total R^2 for Step 1	.07*	.12*
STEP 2 β		
SES	.20*	.30*
Age	.13	-.12
Moderate TBI vs. OI	.07	.00
Severe TBI vs. OI	-.14	-.18*
ΔR^2 for Step 2	.03	.03
STEP 3 β		
SES	.18	.24*
Age	.08	.00
Moderate TBI vs. OI	.07	.01
Severe TBI vs. OI	-.16	-.16
Delayed Alternation Task	-.04	.01
Shape School Control	.14	.01
Shape School Inhibit	.06	.06
Shape School Switch	.14	.17
Shape School Both	-.18	-.01
ΔR^2 for Step 3	.05	.03

Table 5

Summary of hierarchical regression analyses predicting social competence from parent ratings of executive functions

<i>n</i>	Dependent variable	
	ABAS	PKBS/HCSBS
	160	161
Predictors		
STEP 1 β		
SES	.18*	.30*
Age	.05	.10
Total R^2 for Step 1	.03	.10*
STEP 2 β		
SES	.13	.25*
Age	.07	.10
Moderate TBI vs. OI	.09	-.09
Severe TBI vs. OI	-.18*	-.17*
ΔR^2 for Step 2	.05*	.03*
STEP 3 β		
SES	-.00	.11*
Age	-.02	.03
Moderate TBI vs. OI	.15	-.01
Severe TBI vs. OI	-.00	.03
BRIEF GEC	-.29*	-.48*
CBQ	.38*	.27*
ΔR^2 for Step 3	.32*	.42*