Journal of the International Neuropsychological Society (2007), **13**, 298–311.

DOI: 10.1017/S1355617707070324

Self-regulation as a mediator of the effects of childhood traumatic brain injury on social and behavioral functioning

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(Received June 6, 2006; Final Revision October 1, 2006; Accepted October 12, 2006)

Abstract

This study builds on our earlier investigation (see Ganesalingam et al., 2006). We showed previously that children with moderate to severe traumatic brain injuries (TBI) had poorer self-regulation and social and behavioral functioning than their uninjured peers and that self-regulation predicted significant variance in parent- and teacher-rated social and behavioral outcomes, regardless of the presence or absence of TBI. In this study, we examine self-regulation as a mediator of the relationship between TBI and the outcomes. Participants included 65 children with moderate to severe TBI and 65 children without TBI matched for age and gender. Participants were between 6 and 11 years of age. Children completed an assessment of cognitive, emotional, and behavioral self-regulation, and social and behavioral functioning. Mediation was assessed using a bootstrapping approach (a relatively novel statistical method for assessing specific indirect effects in models with multiple mediators). Analyses indicated that, after controlling for socioeconomic status (SES), aspects of self-regulation accounted for individual variation in the outcomes, and acted as a significant mediator of the effects of TBI on the outcomes. Self-regulatory deficits may reflect the relative vulnerability of the prefrontal cortex to TBI and may help account for post-injury difficulties in social and behavioral functioning. (*JINS*, 2007, *13*, 298–311.)

Keywords: Traumatic brain injury, Children, Self-regulation, Social and behavioral functioning, Multiple mediators, Specific indirect effects

INTRODUCTION

Traumatic brain injuries (TBI) annually result in approximately 150,000 hospitalizations and 5000 deaths in children and adolescents below the age of 15 years (Kraus, 1995). Although the number of deaths continues to decrease as a result of improved medical practice (Middleton, 2001), outcomes for the surviving children are often poor. Post-injury outcomes are closely tied to the severity of the TBI (Yeates, 2000). Children with severe TBI display deficits in cognitive skills, academic performance, and adaptive behaviors as well as behavior problems that often include increased aggression, poor temper control, inattention, and hyperactivity (Fletcher et al., 1990; Max et al., 1999; Taylor et al., 1999).

In a recent paper, we examined the impact of childhood TBI on self-regulation and social and behavioral functioning. We also examined the contributions of self-regulation to the prediction of social and behavioral functioning (Ganesalingam et al., 2006). After controlling for socioeconomic status (SES), children with TBI were found to demonstrate significantly poorer self-regulation and social and behavioral functioning than their uninjured peers. Further, aspects of self-regulation significantly predicted social and behavioral functioning, again after controlling for SES, as well as group membership (i.e., presence or absence of TBI). These findings emphasize the negative impact of TBI on children's post-injury outcomes and the importance of self-regulation

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in social and behavioral functioning. However, the study did not directly test whether self-regulation acts as a significant mediator of the effect of childhood TBI on social and behavioral functioning.

Self-regulation is often viewed as a biologically-based attribute that is governed by the prefrontal cortex (Luria, 1973). This multilevel construct has been defined as the capacity to manage one's own thoughts, feelings and actions in adaptive and flexible ways across a range of contexts (Saarni, 1997). Thus, self-regulation can be conceptualized as including three dimensions, namely: cognitive, emotional and behavioral self-regulation. Developmental studies have tended to consider each of these aspects of self-regulation separately (e.g., Barkley, 1997; Dagenbach & Carr, 1994; Krueger et al., 1996; Shields & Cicchetti, 1998a), even though they are suggested to be closely linked (Banerjee, 1997; Lemerise & Arsenio, 2000). Studies that have examined multiple dimensions of self-regulation simultaneously have shown them to be correlated (e.g., Eisenberg & Fabes, 1992). Self-regulation has also been discussed in relation to current conceptualizations of executive functions. The constructs of self-regulation and executive function exhibit considerable overlap, and both constructs have been characterized as including cognitive processes, emotional responses, and behavioral impulses (Barkley, 1997; Isquith et al., 2005).

Self-regulation is a key construct in theories of temperament and affect development (Rothbart, 1989; Rothbart & Bates, 1998), and it is posited to be a major determinant of attention disorders (Barkley, 1997). Developmental studies have shown self-regulation to play a crucial role in children's social competence (Cicchetti, 1994; Eisenberg et al., 2000) and a mediating role for children's social and adaptive behaviors (e.g., Eisenberg et al., 1997). For example, emotional self-regulation in the form of poorly regulated negative affect has been shown to mediate the effects of maltreatment on children's social competence (Shields & Cicchetti, 1998a); in other words, maltreatment affects children's capacity to regulate their emotions, and emotional dysregulation in turn leads to social difficulties. The latter findings indicate the potential importance of studying the role that self-regulation may play as a mediator of the effects of TBI on children's social and behavioral functioning.

Self-regulatory deficits are characteristic of many children following moderate to severe TBI (Max et al., 2004). Impairments in cognitive self-regulation, such as attention, and the ability to plan and organize activities, are often apparent among children after TBI (Anderson et al., 1998; Max et al., 1999). Impairments in emotional self-regulation, including low frustration tolerance, emotional lability, and frequent mood swings are also common in these children (Grattan & Eslinger, 1991). Behavioral self-regulation difficulties including poor inhibition and hyperactivity are also reported among children after TBI (Max et al., 2004).

Deficits in self-regulation are likely to reflect the relative vulnerability of the prefrontal cortex to TBI. The prefrontal cortex is involved in many aspects of self-regulation (Barkley, 1997; Lezak, 1995). Disruption to prefrontal structure and function is common after TBI (Bigler, 2001; Wilde et al., 2005). Lesions to the orbitomedial and dosolateral prefrontal cortex have been linked to regulatory deficits (Stuss & Benson, 1986). Thus, damage to the prefrontal cortex is likely to give rise to impairments in self-regulation that may result in various social and behavioral difficulties after childhood TBI.

Previous research on the outcomes of childhood TBI has paid scant attention to the mediating role of cognitive-behavioral and emotional skills, such as self-regulation, as predictors of children's social and behavioral functioning. The goal of this study was to determine whether the effects of TBI on children's social and behavioral functioning are mediated by cognitive, emotional, and behavioral self-regulation. Statistical methods for assessing mediation when models involve multiple mediators are limited. We used a bootstrapping approach that is a relatively novel method for assessing specific indirect effects in models with multiple mediators. Using data drawn from the same study that we recently presented (Ganesalingam et al., 2006), we tested the hypothesis that cognitive, emotional, and behavioral aspects of self-regulation would act as mediators of the effects of childhood TBI on social and behavioral functioning.

METHODS

Study Design and Recruitment

This study employed a cross-sectional design with two groups, consisting of children with moderate to severe TBI and uninjured children. Sixty children with TBI were recruited from Australia, specifically from three children's hospitals including the Royal Children's Hospital, Victoria, Sydney Children's Hospital, and the Children's Hospital at Westmead, New South Wales. These children were identified *via* hospital record review. We also recruited five children with TBI from primary schools in New Zealand. These children were identified by school personnel as having been assigned a teacher's aide to assist them with completing schoolwork after sustaining a TBI. Children with TBI who fulfilled the inclusion criteria were sent information about the study and a consent form. Children and their parents who were interested in participating returned the consent form, and were then contacted *via* telephone to schedule an assessment. Children with TBI and their parents (more than two thirds of those originally approached) volunteered to participate in the study.

Uninjured children for the comparison group were first approached in Australia. Difficulties in ascertaining the required sample within the timeframe of the study led to the recruitment of uninjured children in New Zealand as well. Within the available timeframe, five children from Australia and 60 children from New Zealand were identified. The children were recruited from local primary schools. On gaining permission from school principals, children were given

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a newsletter, information about the study, and a consent form to take home to their parents or caregivers. On the newsletter, parents were asked whether their child had had a hospital admission and the reason for the admission. Children were excluded from the study if there was any suspicion of head injury associated with the hospital admission. Children were also excluded if they had a history of any learning, attentional or developmental disorders. The parents of eligible children were contacted *via* telephone and an appointment for an assessment was arranged with those who agreed to participate. Of the families approached, 67% agreed to participate in this study. The data were obtained in compliance with the regulations of the Ethics in Human Research Committees of the Royal Children's Hospital, Victoria, the Sydney Children's Hospital, the Children's Hospital at Westmead, New South Wales, Australia, and the School Boards in Australia and New Zealand.

Research Participants

Participants included 65 children with moderate to severe TBI and 65 uninjured children. Children in the TBI group had sustained injury between the ages of 2 and 9 years, and had a mean Glasgow Coma Scale (GCS; Teasdale & Jennett, 1974) score of 10.5 ($SD = 2.90$). All participants were between 6 and 11 years old when assessed, and they were all attending a mainstream primary school. The TBI and comparison groups did not differ significantly in age at assessment, gender, socioeconomic status (SES), or the proportion of Caucasian participants. SES was determined by combining the mean *z*-score for maternal education and occupation. A more detailed description of the sample characteristics, the definition of SES, and the measures used to determine SES can be found in Ganesalingam et al. (2006). Participants in both groups were predominantly Caucasian (95%). The remaining 5% of participants in each group were of Asian, Polynesian, or Middle-Eastern descent. All participants spoke English as their first language.

The inclusion criteria for children with TBI were as follows: (a) documented evidence of closed head injury of an unintentional nature (e.g., motor-vehicle accidents, falls, and sporting accidents); (b) time since injury from 2 to 5 years; and (c) medical records with documented evidence of moderate to severe TBI. Severe TBI was defined by the lowest GCS score of 8 or less. Moderate TBI was defined as a GCS score of 9 to 12, or a GCS score of 13 to 15 accompanied by skull fracture, intracranial lesion, or diffuse cerebral swelling on routine clinical neuroimaging; posttraumatic neurological abnormality; or loss of consciousness longer than 15 minutes. Children were excluded if they presented with any of the following characteristics: (a) previous head injury; (b) documented learning or attention disorder prior to injury; or (c) history of neurological or developmental disorders. All children with severe TBI ($n = 32$) had intracranial abnormalities on CT and/or MRI scans. Among children with moderate TBI ($n = 33$), 24 (73%) had abnormal findings on CT and/or MRI scans. Motor-vehicle accident was the most common cause of injury, followed by falls, consistent with the epidemiology of TBI (Kraus, 1995).

Measures

Children's social and behavioral functioning

Social and behavioral functioning was assessed using the parent-rated Eyberg Child Behavior Inventory (ECBI; Eyberg & Robinson, 1983), the teacher-rated Sutter-Eyberg Student Behavior Inventory-Revised (SESBI-R; Funderburk & Eyberg, 1989), and the parent and teacher versions of the Social Skills Rating System (SSRS; Gresham & Elliot, 1990). The ECBI and the SESBI-R assess the intensity of a variety of behavior problems that children may display at home and school, respectively. Higher scores on the ECBI and the SESBI-R reflect poorer functioning. The SSRS examines everyday social behaviors that allow children to interact with others effectively, including sharing, helping, initiating relationships, giving compliments, and requesting help. The parent-rated SSRS assesses four subscales (Cooperation, Assertion, Responsibility, and Self-control), whereas the teacher-rated SSRS assesses three of the same dimensions (Cooperation, Assertion and Self-control). Higher scores on the SSRS indicate better social and behavioral functioning.

Children's self-regulation

Children were administered the Matching Familiar Figures Test (MFFT; Kagan, 1966) to assess cognitive self-regulation. Children are required to match a single drawing of a familiar figure to an array of six variants of the figure, only one of which is identical to the target stimulus. Children's performance on this task yielded two indices of impulsivity: (i) response errors (i.e., number of errors made prior to arriving at the correct answer), and (ii) response latency (i.e., time taken to arrive at the first response). Raw scores on these subscales were analyzed using principal components analysis. One component was extracted and was used in the subsequent analyses. Higher scores indicate poorer self-regulation.

The Sky Search, Score, and Opposite Worlds subtests of the Test of Everyday Attention for Children (TEA-Ch; Manly et al., 1999) were also used to assess cognitive self-regulation. An average of the scaled scores of the three subtests (described below) was used in the subsequent analyses. Higher scores indicate better cognitive self-regulation.

On Sky Search, children are required to (i) identify and circle as quickly as possible as many "target" spaceships on a sheet filled with similar distracter spaceships, and (ii) circle the spaceships on another sheet, which contains no distracter spaceships, again as quickly as possible. The time taken to complete the second task is subtracted from the time taken to complete the first task, to control for motor speed. This task thus assesses selective or focused attention independent of motor speed.

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The Score subtest was selected to provide a measure of children's capacity to regulate or sustain attention without assistance. This task features laser beam sounds on an audiocassette. Each sound is followed by a silent interval. There are 9 to 15 sounds per set. Children are required to count and report the total number of sounds heard per set. There are 10 sets in total, each lasting 30 to 40 seconds. Children are given a point for each set that is correctly counted.

Opposite Worlds is a timed task that assesses attentional control by examining children's capacity to suppress an automatic verbal response. Children are required to follow the picture of a path in a booklet scattered with the digits "1" and "2," and to name each digit. On the first trial, which operates under the "same world" rule, participants say "one" for the numeral 1 and "two" for the numeral 2. On the second trial, which operates under the "opposite world" rule, participants are instructed to say "two" for the numeral 1 and "one" for the numeral 2. The amount of time taken to complete each trial is used to score the task. A score based on only the Opposite Worlds trial was used in the current study.

Emotional self-regulation was assessed using the parent-rated Emotion Regulation Checklist (ERC; Shields & Cicchetti, 1998b). The ERC has two subscales: emotion regulation, which includes items reflecting appropriate affective displays, empathy, and emotional awareness, where higher scores reflect better emotional self-regulation, and lability/negativity, which includes items reflecting inflexibility, mood lability, and negative affect, where higher scores indicate poorer emotional self-regulation. The raw scores from the two scales were used in this study.

Behavioral self-regulation was assessed using a 10-minute Delay of Gratification Task (DGT; Mischel & Ebbesen, 1970). The task assesses children's capacity to inhibit behavioral responses and to use strategies that help them delay immediate gratification and wait for a more desired reward (Rodriguez et al., 1989; Sethi et al., 2000). Children were videotaped during the task. The experimenter placed a bell and possible rewards (i.e., small candies) in front of the child; two candies on one side of the bell, and one candy on the other side. Children were told that they would receive two candies if they waited for the experimenter to return to the room, but that they would receive only one candy if they rang the bell to call the experimenter before she returned. Two measures of behavioral self-regulation were derived from the task: (a) distraction strategies, which is a count of the number of behavioral strategies used to help delay gratification (e.g., looking away from the rewards, restating the rules, playing games with one's own hands and feet), coded using methods employed in previous research (e.g., Rodriguez et al., 1989; Sethi et al., 2000), and (b) behavioral inhibition as indexed by the amount of time waited prior to receiving the rewards. The raw scores on the two measures were used in this study. Higher scores indicate better functioning on both measures.

Additional information regarding the validity and reliability of these measures is available in our previous study (see Ganesalingam et al., 2006).

Data analyses

The goal of the data analyses was to examine whether the effects of TBI on social and behavioral functioning were mediated by self-regulation. For each dependent variable (i.e., parent- and teacher-rated social and behavioral functioning), we tested a multiple mediator model that estimates 4 different parameters: (1) the direct effect of group membership (i.e., presence or absence of TBI) on the proposed mediator variables (i.e., cognitive, emotional and behavioral self-regulation including the MFFT, TEA-Ch, ERC emotion regulation, ERC lability/negativity, DGT distraction strategies, and DGT behavioral inhibition), (2) the direct effect of the mediators on the dependent variables (i.e., parent-rated ECBI, SSRS Cooperation, Assertion, Responsibility and Self-control, and eacher-rated SESBI-R, SSRS Cooperation, Assertion, and Self-control), (3) the total (i.e., direct and indirect) effect of group membership on the dependent variables, and (4) the specific indirect effect of group membership on the dependent variables through each proposed mediator. Each model included SES as a covariate, and each hypothesis was tested with a confidence interval. Current analyses utilized 5000 bootstrap resamples to generate 95% confidence intervals.

An example of a multiple mediator model (adapted from Preacher & Hayes, 2004) is depicted in Figure 1. Panel A of this model represents the total effect of the independent variable (X) on the dependent variable (Y), represented with the unstandardized path coefficient c. Panel B represents the direct effect of X on Y (path c′) and the indirect effects of X on Y *via* the mediators (M). The specific indirect effect of X on Y *via* any one mediator is defined as the product of the two unstandardized paths linking X to Y *via* that particular mediator. The total indirect effect of X on Y is the sum of the specific indirect effects. The total effect of X on Y (path c) is the sum of the direct effect (path c′) and the total indirect effect.

The model parameters were estimated simultaneously using a bootstrapping approach (Preacher & Hayes, 2004).

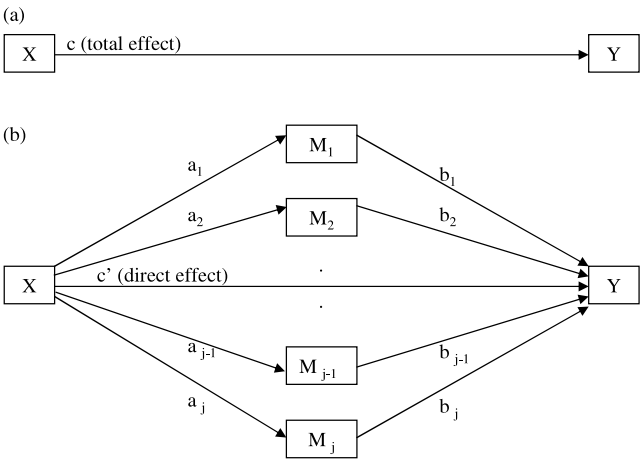

Fig. 1. A multiple mediator model (adapted from Preacher & Hayes, 2004).

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Bootstrapping using confidence intervals avoids assumptions about sampling distributions by empirically estimating the sampling distribution of a statistic from the available data and using it to calculate *p*-values and establish confidence intervals. The available data are used as a "pseudo-population" and randomly resampled with replacement, and an estimate of the desired statistic is generated for each resample. The distribution of the statistic over multiple resamples of the existing data is treated as an empirical estimate of the sampling distribution of that statistic. From the bootstrap sampling distribution, hypotheses can be tested and confidence intervals constructed. When used to assess mediation, bootstrapping avoids problems inherent in the "causal steps" approach advocated by Baron and Kenny (1986) and makes fewer assumptions about the sampling distribution than existing statistical methods for assessing mediation effects, such as the Sobel test (Sobel, 1988). The bootstrapping approach can be implemented using an SPSS macro that is publicly available (http://www.comm.ohio-state.edu/ahayes/). The procedure uses ordinary least squares to estimate all model paths.

RESULTS

Direct Effect of Group Membership on Self-regulation

After controlling for SES, group membership (i.e., presence or absence of TBI) predicted significant variance in each mediator variable (i.e., poorer performance on the MFFT, TEA-Ch, ERC emotion regulation and lability/negativity subscales, the DGT distraction strategies, and behavioral inhibition subscales) as illustrated in Figures 2 and 3.

Direct Effect of Self-regulation on Social and Behavioral Functioning

Emotional self-regulation measures predicted significant variance across parent- and teacher-rated measures of social and behavioral outcomes. Emotion regulation was associated with better social and behavioral functioning, whereas lability/negativity was related to poorer social and behavioral outcomes. Emotional self-regulation had stronger relations with parent-rated outcomes than teacher-rated outcomes, although shared rater variance may have contributed to these associations. Cognitive and behavioral self-regulation predicted only a few of the social and behavioral outcomes. The DGT behavioral inhibition subscale predicted higher scores on the parent-rated SSRS Assertion subscale. Further, the DGT distraction strategies subscale predicted significant variance in the SESBI-R; however, this relation was not in the expected direction, that is, greater use of distraction strategies was related to more behavior problems. The MFFT predicted lower ratings on the teacher-rated SSRS Self-control subscale. These relations were not as strong as those between emotional self-regulation and the outcomes. However, cognitive and behavioral self-regulation were directly assessed with the children and therefore do not have shared rater or method variance. The relationships between self-regulation and social and behavioral functioning are summarized using path diagrams (see Fig. 2A to 2E for parent-rated social and behavioral functioning and Fig. 3A to 3D for teacher-rated outcomes).

Total Effects, Direct Effects, and Total Indirect Effects of Group Membership

The total effect of group membership (i.e., without inclusion of self-regulatory skills) was significant for each measure of social and behavioral functioning, suggesting that TBI is associated with behavior problems and less competent social skills (see Table 1). The direct effect of group membership on the social and behavioral outcomes, independent of self-regulatory skills, was not significant. Moreover, as shown in Table 1, the total indirect effect of group membership on social and behavioral functioning was significant for both parent- and teacher-rated outcomes, with the exception of the teacher-rated SSRS Cooperation subscale. These findings suggest that, when self-regulation is taken into account, group membership no longer directly contributes to social and behavioral outcomes; rather, its relationship with the outcomes is mediated by self-regulation.

Specific Indirect Effects of Group Membership

Examination of specific indirect effects showed that the ERC emotion regulation and lability/negativity subscales were the most consistent mediators of the effects of group membership on social and behavioral functioning. The presence of TBI was associated with poorer emotion regulation and greater lability/negativity, and each in turn was associated with more parent- and teacher-rated social and behavioral difficulties (i.e., higher scores on the ECBI and lower scores on the parent-rated SSRS Assertion, Responsibility, and Self-control subscales, with a similar pattern on the teacher-rated SESBI-R, SSRS Assertion and Self-control subscales). These results highlight the unique role of emotional self-regulation as a mediator of the relationship between group membership and social and behavioral outcomes, controlling for all other self-regulation variables and SES.

Only two specific indirect effects involving cognitive and behavioral self-regulation were significant. The presence of TBI predicted poorer behavioral inhibition on the DGT, which in turn was related to lower scores on the parent-rated SSRS Assertion subscale. Further, TBI was related to poorer performance on the MFFT, which in turn was associated with lower scores on the teacher-rated SSRS Self-control subscale.

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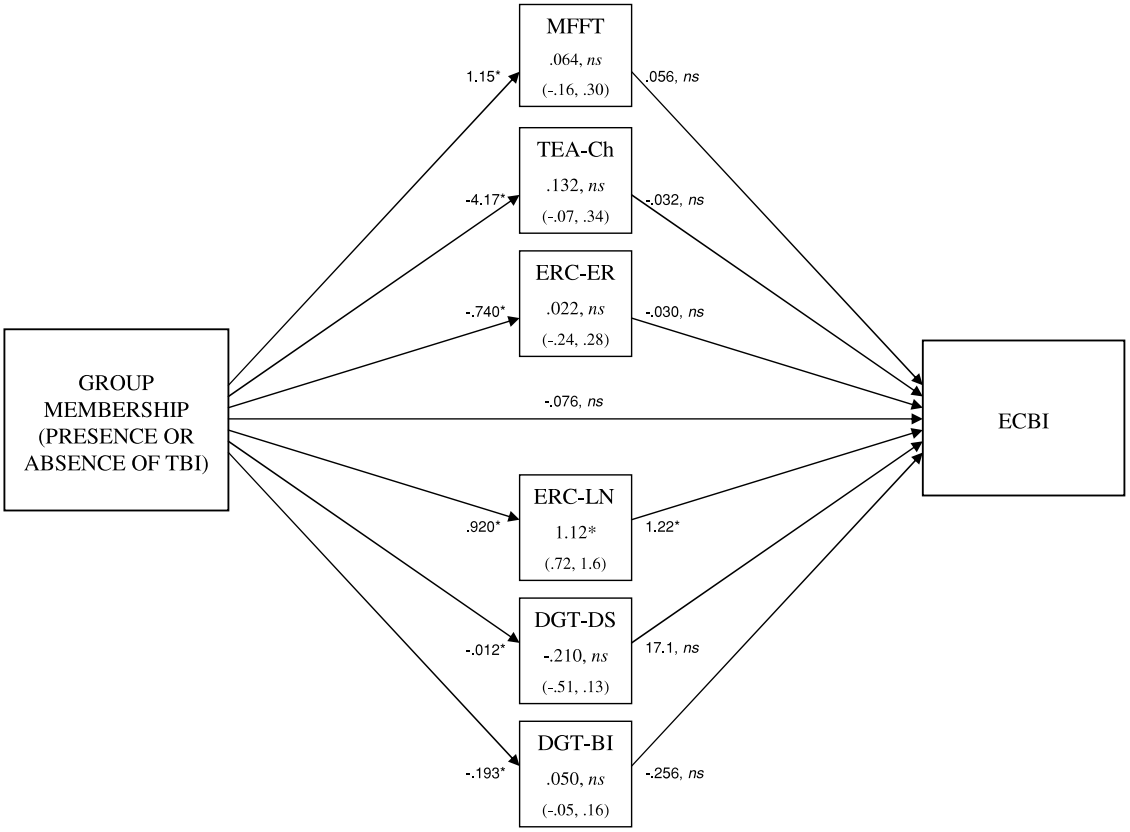

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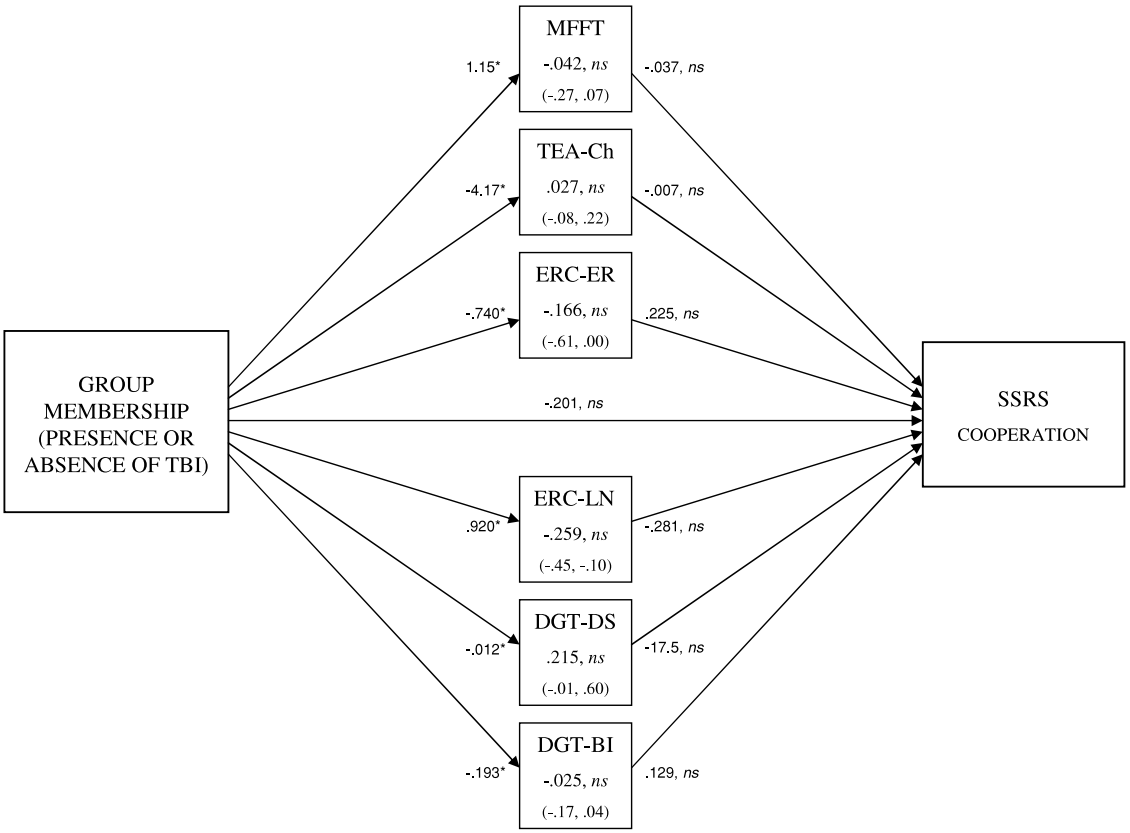

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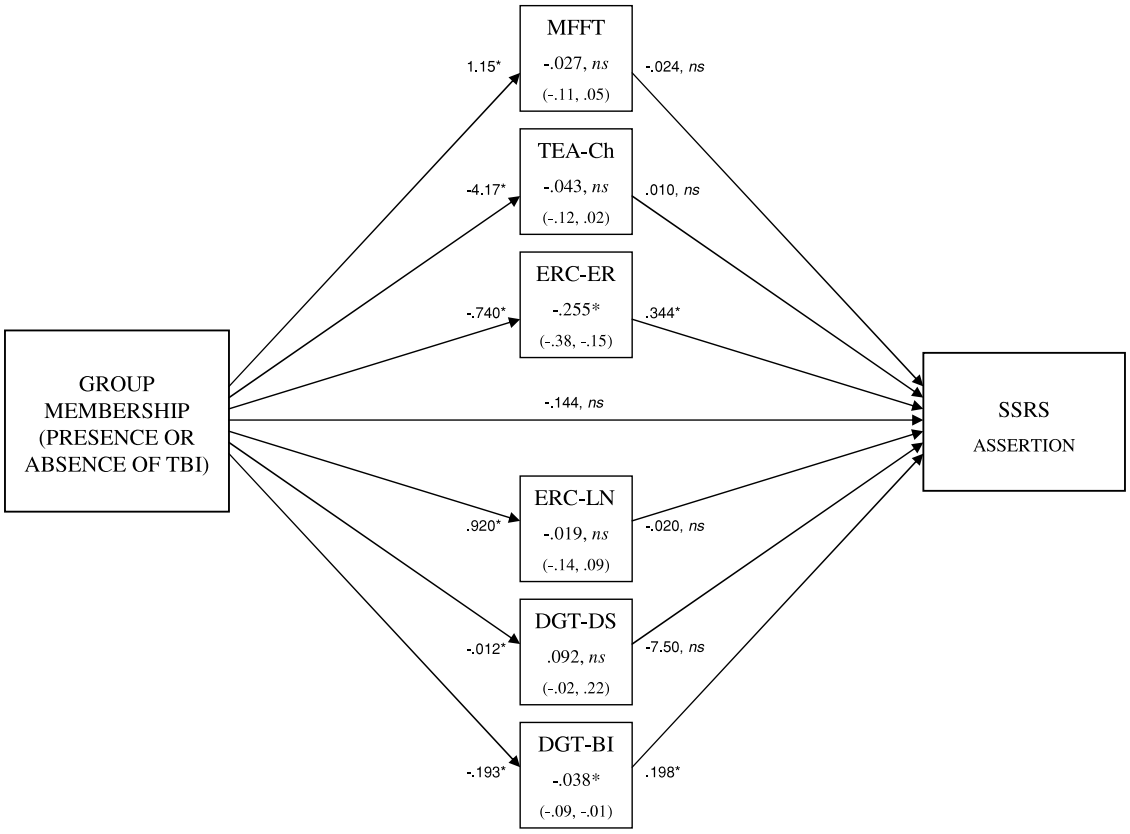

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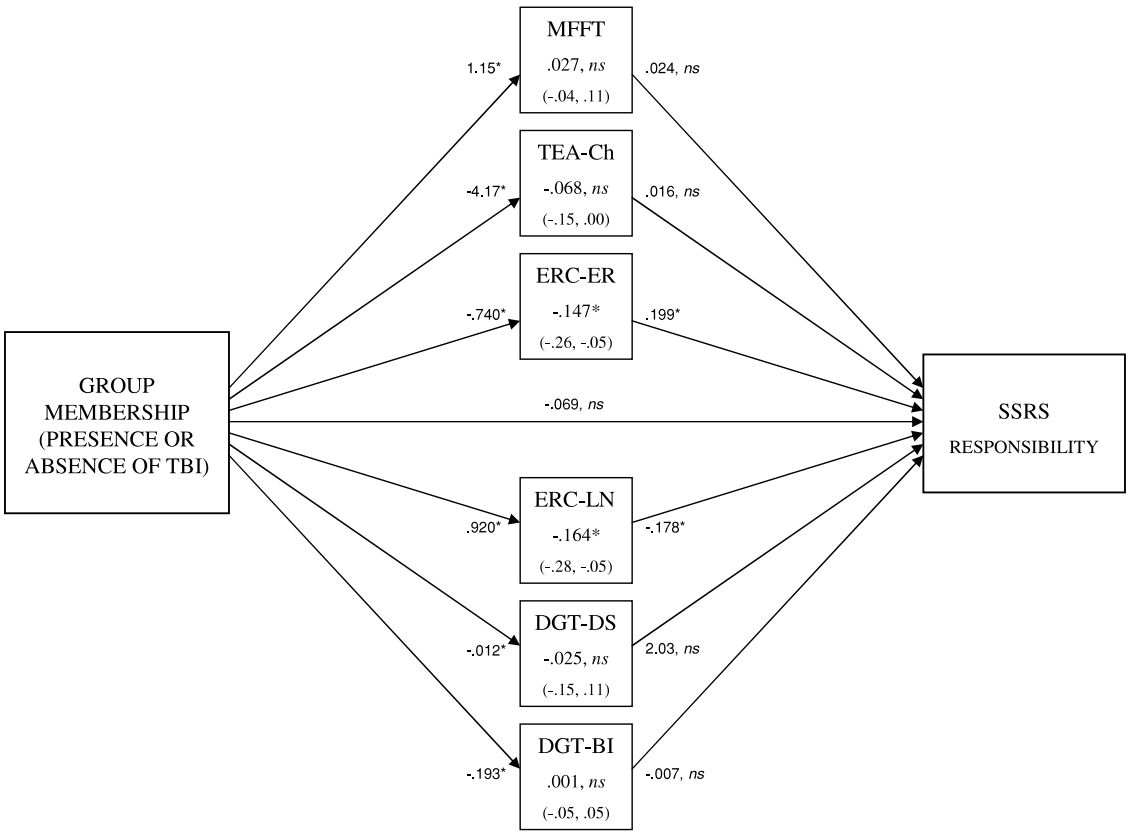

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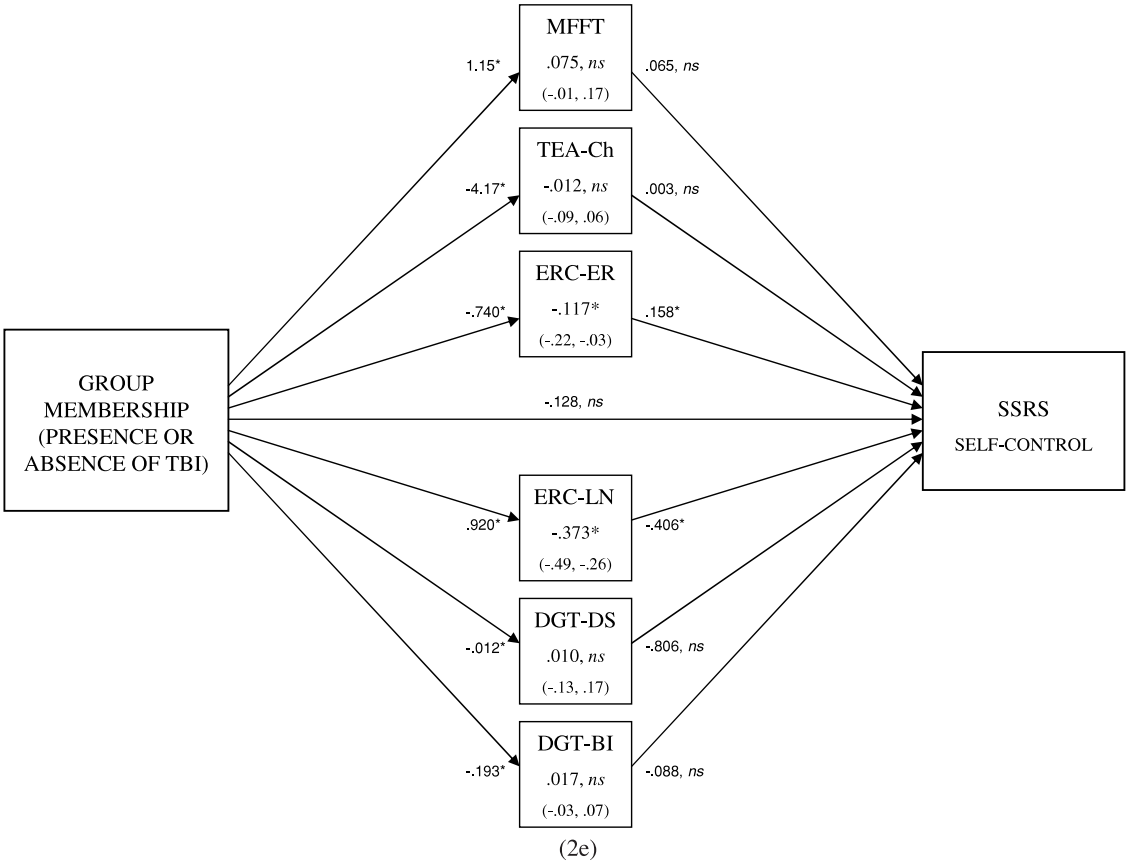

Fig. 2. Path diagrams depicting the relationships among group membership, self-regulation measures—Matching Familiar Figures Test (MFFT), Test of Everyday Attention for Children (TEA-Ch), Emotion Regulation Checklist–Emotion Regulation (ERC-ER) and Lability/Negativity (ECR-LN), Delay of Gratification Task–Distraction Strategies (DGT-DS) and Behavioral Inhibition (DGT-BI), and five parent-rated social and behavioral outcomes (a) Eyberg Child Behavior Inventory (ECBI); (b) Social Skills Rating System (SSRS) Cooperation; (c) Assertion; (d) Responsibility; and (e) Self-control. The single-arrow lines between the variables are labeled with the unstandardized coefficients. The unstandardized coefficient and 95% confidence interval of the indirect effect of group membership on social and behavioral outcomes via self-regulation measures are presented in the boxes, below each self-regulation variable. $*p < .05$.

DISCUSSION

This study examined the interplay among childhood TBI, self-regulation, and social and behavioral functioning. The central hypothesis was that cognitive, emotional, and behavioral aspects of self-regulation would act as mediators of the effects of childhood TBI on social and behavioral outcomes. The current findings provide evidence in support of the hypothesis. Self-regulation variables mediated the significant relationship between childhood TBI and social and behavioral functioning.

When specific indirect effects were examined, emotional self-regulation stood out as the strongest and most consistent mediator. Emotional self-regulation was a significant predictor of multiple aspects of parent- and teacher-rated social and behavioral outcomes and a significant mediator of the effects of TBI on those outcomes. These results suggest that emotional self-regulation may be a core deficit in children who display social and behavioral difficulties after TBI. This finding is consistent with developmental studies that have demonstrated the contributions of emotional self-regulation to social competence in children with externalizing behavioral problems (Eisenberg et al., 1995), and children who have been maltreated (Shields & Cicchetti, 1998a).

The relationships between emotional self-regulation and social and behavioral functioning are confounded in part by shared rater and method variance, given that parents rated emotional self-regulation and social and behavioral outcomes. This may explain why the relationships with emotional self-regulation were stronger for parent-rated social and behavioral outcomes than for teacher-rated outcomes. Similar complications surrounding shared method variance have been encountered in other developmental research (e.g., Eisenberg et al., 2000). However, emotional self-regulation as rated by parents did predict significant unique variance in the teacher-rated social and behavioral outcomes and also mediated the influence of TBI on the teacher-rated

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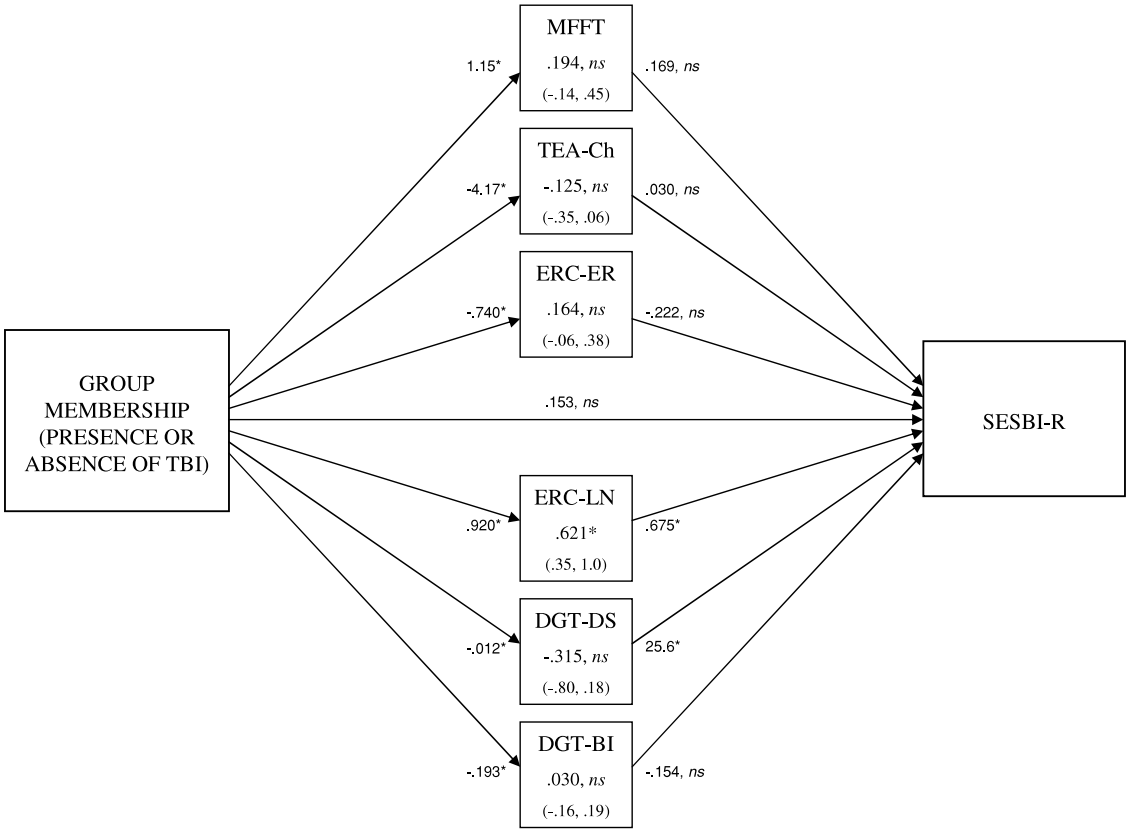

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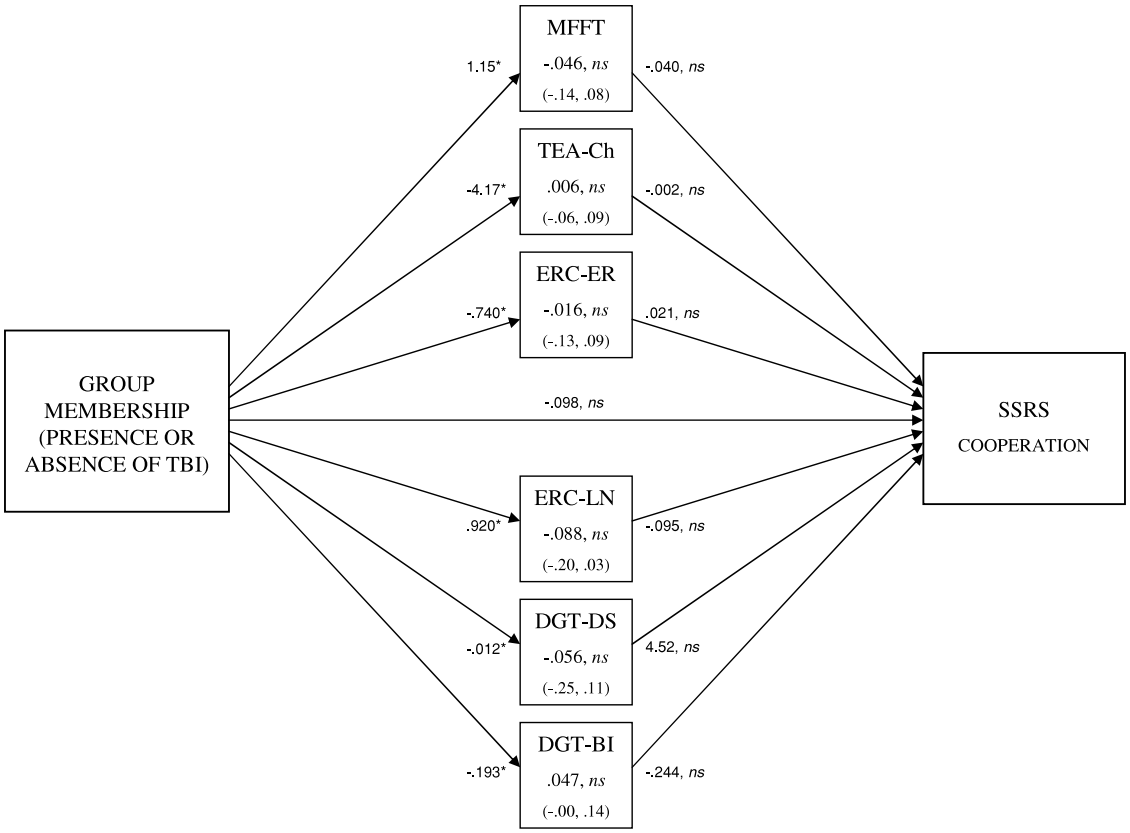

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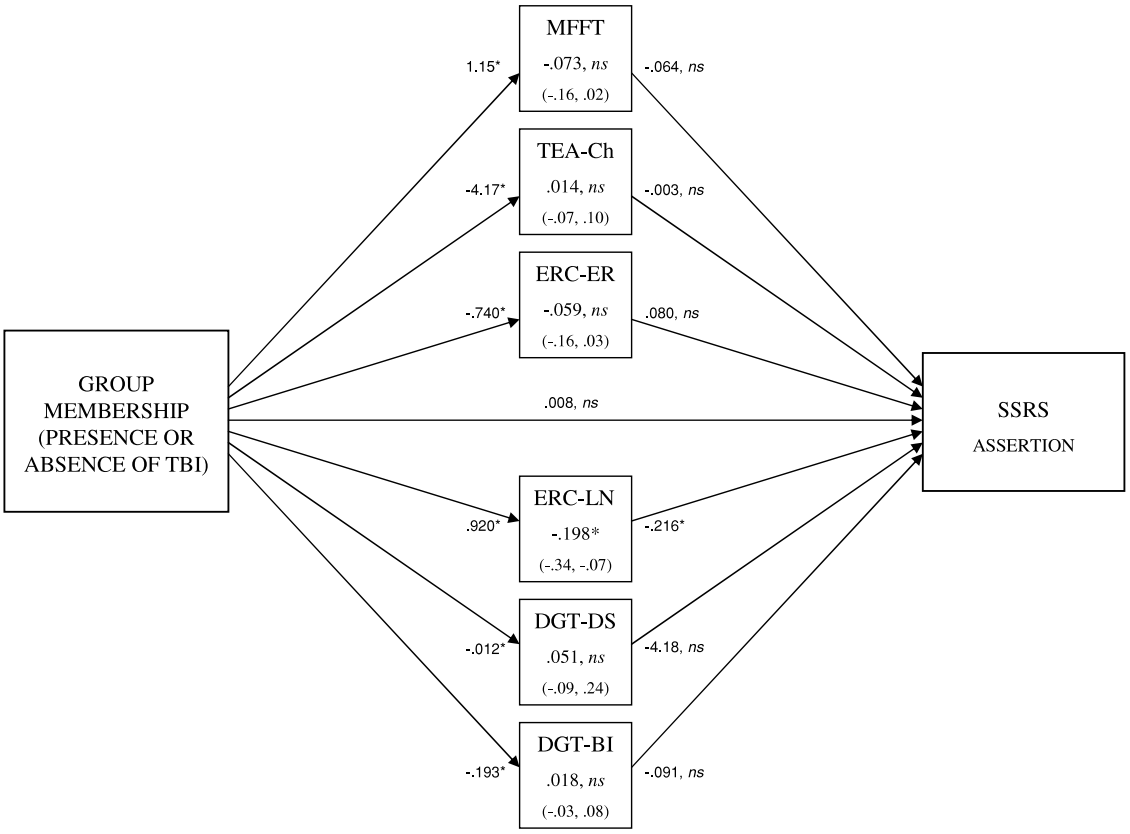

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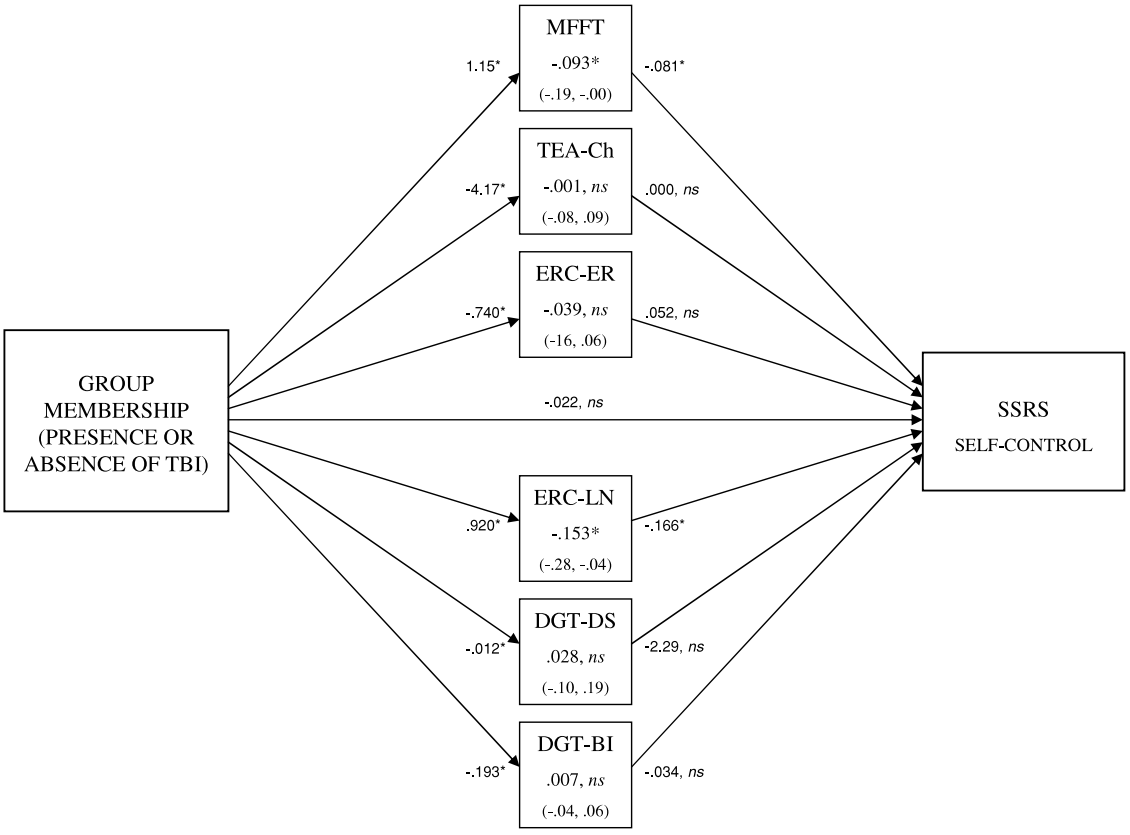

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Table 1. Summary of the total and direct effects of group membership on parent- and teacher-rated social and behavioral outcomes, and the total indirect effects of group membership on the outcomes *via* self-regulation measures

	Total effect of IV on DV (path c)		Direct effect of IV on DV (path c′)		Total indirect effect of IV on DV via MV (paths ab)	
Dependent variable	B	(SE)	B	(SE)	B	(SE)
Parent-reported						
ECBI	1.10*	(.172)	−.076	(.252)	1.18*	(.247)
SSRS Cooperation	−.451*	(.167)	−.201	(.306)	−.250*	(.133)
SSRS Assertion	−.434*	(.053)	−.144	(.083)	−.290*	(.083)
SSRS Responsibility	−.445*	(.053)	−.070	(.086)	−.375*	(.094)
SSRS Self-control	−.528*	(.064)	−.128	(.095)	−.400*	(.083)
Teacher-reported						
SESBI-R	.723*	(.155)	.153	(.256)	.570*	(.244)
SSRS Cooperation	−.249*	(.058)	−.098	(.105)	−.152	(.100)
SSRS Assertion	−.240*	(.062)	.008	(.106)	−.248*	(.098)
SSRS Self-control	−.273*	(.059)	−.022	(.103)	−.251*	(.092)

*$p < .05$

B = unstandardized coefficient; SE = standard error; IV = independent variable (group membership, i.e., presence or absence of TBI); DV = dependent variable (parent- and teacher-rated social and behavioral outcomes); MV = mediator variables (cognitive, emotional and behavioral and self-regulation); ECBI = Eyberg Child Behavior Inventory; SSRS = Social Skills Rating System; SESBI-R = Sutter Eyberg Student Behavior Inventory-Revised.

outcomes. The latter results suggest that the contributions of emotional self-regulation to social and behavioral outcomes were not entirely tainted by shared rater variance, although shared method variance may still account for some of the findings.

Contrary to expectations, measures of cognitive and behavioral self-regulation predicted unique variance in only select aspects of social and behavioral outcomes and did not consistently act as mediators of the effects of childhood TBI on social and behavioral functioning. Both cognitive and behavioral self-regulation constructs were assessed directly with the children, whereas social and behavioral outcomes were rated by parents and teachers. Therefore, the findings are independent of any shared rater and method variance. The current findings provide somewhat limited evidence of the relations between cognitive and behavioral self-regulation and social and behavioral functioning, but these results are in support of the theoretical models of social competence that highlight the direct and indirect contributions of self-regulation (Barkley, 1997; Shields et al., 1994). The limited support for these relations in this instance may be because of the particular measures used to assess cognitive and behavioral self-regulation, which may not be related to the specific social and behavioral outcomes examined. Research is needed to determine what, if any, specific aspects of cognitive and behavioral self-regulation are related to social and behavioral functioning in children after TBI. Further, previous developmental studies have tended to employ measures that include elaborate coding schemes and interpretation of children's functioning (e.g., Eisenberg et al., 1997), whereas, the current measures were somewhat brief. Thus, it is possible that the current measures did not adequately capture children's cognitive and behavioral self-regulatory skills.

These findings may also be because of measures such as the Delay of Gratification Task distraction strategies not being appropriate for the current age group of children. The use of overt distraction strategies to delay immediate gratification may be indicative of good regulation among younger children, but among older children the use of such strategies may reflect poorer regulation, that is, deficits in the internalization of regulation. The nature of this mea-

Fig. 3. Path diagrams depicting the relationships among group membership, self-regulation measures—Matching Familiar Figures Test (MFFT), Test of Everyday Attention for Children (TEA-Ch), Emotion Regulation Checklist–Emotion Regulation (ERC-ER) and Lability/Negativity (ECR-LN), Delay of Gratification Task–Distraction Strategies (DGT-DS) and Behavioral Inhibition (DGT-BI), and five teacher-rated social and behavioral outcomes (a) Sutter Eyberg Student Behavior Inventory–Revised (SESBI-R); (b) Social Skills Rating System (SSRS) Cooperation; (c) Assertion; (d) Self-control. The single-arrow lines between the variables are labeled with the unstandardized coefficients. The unstandardized coefficient and 95% confidence interval of the indirect effect of group membership on social and behavioral outcomes via self-regulation measures are presented in the boxes, below each self-regulation variable. *$p < .05$.

https://doi.org/10.1017/S1355617707070324 Published online by Cambridge University Press

sure could be a potential explanation for the significant prediction of the SESBI-R in the opposite direction. However, the current findings do not necessarily support this understanding. The mean number of overt distraction strategies used is lower for the TBI group than the comparison group (see Ganesalingam et al., 2006). Thus, a more likely explanation is that the task was appropriate for the younger (i.e., 6- and 7-year-old) than older (i.e., 10- and 11-year-old) children in this sample. A group by age at assessment interaction term predicted significant variance in the individual differences in children's performance on the DGT distraction strategies.

Comparable to the current findings, Yeates et al. (2004) reported cognitive processes such as pragmatic language and executive functions to account for little, if any, of the variance in children's social outcomes, and social problem-solving to be a weak mediator at best. They concluded that the lack of support for the mediation hypothesis does not refute the models of social competence described in previous research (e.g., Dodge et al., 2002; Lemerise & Arsenio, 2000), but suggested that other variables may need to be included in the theoretical model in order to account for more variance in the outcomes. The current findings and those of Yeates et al. (2004) suggest that variables other than cognitive processes need to be taken into account to better understand children's social and behavioral outcomes, and that the measures that tap purely cognitive aspects of self-regulation and/or executive functions (e.g., MFFT) tend to have only weak relations with social and behavioral outcomes. The measures that tap a broader range of self-regulatory processes, including emotional and behavioral functioning (e.g., the Behavior Rating Inventory of Executive Function; BRIEF), are more likely to be related to social and behavioral outcomes (e.g., Mangeot et al., 2002).

Although the study findings are generally consistent with the central hypothesis, they must be considered tentatively in light of several methodological limitations. As discussed in Ganesalingam et al. (2006), the current TBI sample was recruited predominantly from Australia, and the comparison group was recruited predominantly from New Zealand, which could have potentially biased the results. However, Australia and New Zealand are culturally alike in terms of health and education standards and migration patterns (Australian Bureau of Statistics, 2001; National Health Information Management Advisory Council, 2001), and the current TBI and comparison groups did not differ in SES. Thus, the disproportionate recruitment across countries is unlikely to have been a significant confound.

Another limitation is that the cross-sectional study design involved concurrent data on self-regulation and social and behavioral functioning. This constrains us from drawing definitive causal inferences. However, the evidence for the role of self-regulation as a determinant of social and behavioral functioning is consistent with other studies that have incorporated longitudinal data (e.g., Eisenberg et al., 1997), as well as with current models of children's social development (Olson et al., 2005).

Yet another limitation is that children's language ability was not assessed in this study. Thus, whether children with TBI demonstrate deficits in self-regulation and social and behavioral functioning independent of language abilities, or if the association between self-regulation and social and behavioral functioning holds even when controlling for language abilities cannot be determined. The inclusion of children's language abilities in the theoretical model may help explain additional variance in the social and behavioral outcomes.

The age at injury of the TBI group was wide, ranging from 2 to 9 years, and yet age at injury was not controlled for in the current analyses, which could be considered a potential limitation. This is because in our sample, age at injury and age at assessment were strongly correlated. Still, the relations between these variables and the outcomes were examined. Correlation analyses showed that age at injury was related to only two outcome measures. Because of the confounding of the age variables, we chose not to report these analyses in the current paper.

Study limitations also involve measurement issues. The measure used to assess emotional self-regulation (i.e., ERC), and the measures of social and behavioral outcomes (i.e., ECBI, SESBI-R, and SSRS) are believed to assess conceptually distinct constructs, but the measures display some overlap in item content. Specifically, the amount of overlap between the ERC and each of the social and behavioral outcome measures ranged from 14% (between the ERC and the ECBI) to 18% (between the ERC and the SESBI-R). One the other hand, previous research has demonstrated significant relationships between these constructs using different measures (e.g., Shields & Cicchetti, 1998a). Thus, the relationships found in this study are likely to be meaningful. Further, emotions, and the regulation of emotions, are essential for social competence (Bradley, 2000; Schore, 1994; Shields & Cicchetti, 1998a). Dys-regulated emotions (e.g., attenuated empathy, poor emotion understanding, and contextually inappropriate displays of positive and negative emotions) are closely linked to externalizing behavior problems (Casey, 1993; Cook et al., 1994). Not surprisingly, emotional self-regulation plays a vital mediating role, for instance, when mediating the effects of maltreatment on children's social competence (e.g. Shields et al., 1994), and when mediating the effects of TBI on social and behavioral outcomes, as seen in this study.

Another measurement concern is that cognitive and behavioral self-regulation were assessed directly with the children, whereas parent ratings were used to assess emotional self-regulation, as well as social and behavioral functioning. Direct behavioral observations of children's emotional self-regulation and social and behavioral functioning would have been desirable and may have shown a different and possibly richer pattern of behaviors but was beyond the scope of this study.

Despite these limitations, the present findings contribute to our understanding of the social outcomes of childhood TBI, and highlight the relations among childhood

TBI, self-regulation, and social and behavioral functioning in school-age children several years after injury. Importantly, the study provides evidence in support of the notion that self-regulation (or at least emotional self-regulation) mediates the effects of TBI on children's social and behavioral functioning. This finding has several important scientific and clinical implications. The finding adds support to the theories and models focusing on the role of children's regulatory skills in their social development and competence (e.g., Olson et al., 2005; Rothbart & Bates 1998; Rueda et al., 2005; Yeates et al., in press). The findings should also prompt research in developmental psychopathology to focus on the self-regulatory processes underlying various developmental disorders that share common social and behavioral difficulties, such as attention deficit hyperactivity disorder, oppositional defiant disorder, and conduct disorder (Barkley, 1997; Bradley, 2000). For instance, the current findings suggest that emotional self-regulation plays an important role in parent- and teacher-rated social and behavioral outcomes. Shared method variance aside, developmental psychopathology research may wish to asses emotional self-regulation in children with developmental disorders to better understand their social and behavioral difficulties. Finally, the findings suggest that the clinical evaluation of children with TBI needs to include measures not only of cognitive skill but also of emotional self-regulation, if the goal is to understand and predict children's social and behavioral functioning.

ACKNOWLEDGMENTS

The research presented here has no financial or other relationships that could be interpreted as a conflict of interest. The authors acknowledge the contributions of Ms. Naomi Brooks at the Sydney Children's Hospital and Dr. Adam Schienberg at the Children's Hospital at Westmead, New South Wales, Australia, for their support in the recruitment of children with TBI at the respective hospitals. Special thanks to Dr. Andrew Hayes for his comments during the preparation of this manuscript. A preliminary version of this paper was presented at the annual meeting of the International Neuropsychological Society in Missouri, USA; February 2005.

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