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Dimensions of postconcussive symptoms in children with mild traumatic brain injuries

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Abstract

The dimensions of postconcussive symptoms (PCS) were examined in a prospective, longitudinal study of 186 8 to 15 year old children with mild traumatic brain injuries (TBI). Parents and children completed a 50-item questionnaire within 2 weeks of injury and again at 3 months after injury, rating the frequency of PCS on a 4-point scale. Common factor analysis with target rotation was used to rotate the ratings to four hypothesized dimensions, representing cognitive, somatic, emotional, and behavioral symptoms. The rotated factor matrix for baseline parent ratings was consistent with the target matrix. The rotated matrix for baseline child ratings was consistent with the target matrix for cognitive and somatic symptoms but not for emotional and behavioral symptoms. The rotated matrices for ratings obtained 3 months after injury were largely consistent with the target matrix derived from analyses of baseline ratings, except that parent ratings of behavioral symptoms did not cluster as before. Parent and child ratings of PCS following mild TBI yield consistent factors reflecting cognitive and somatic symptom dimensions, but dimensions of emotional and behavioral symptoms are less robust across time and raters. (*JINS*, 2009, *15*, 19–30.)

Keywords: Nervous system trauma, Pediatric, Postconcussion syndrome, Factor analysis, Parent-child agreement, Prospective studies, Head injuries

INTRODUCTION

Traumatic brain injuries (TBI) account for substantial mortality and morbidity among children and adolescents (Kraus, 1995). Moderate and severe injuries are more likely to result in negative outcomes than milder injuries (Yeates, 2000). However, the vast majority of TBI among children are mild in severity. Approximately 500,000 children ages 14 and younger sustain TBI resulting in emergency department visits annually in the United States, and 80–90% of them can be classified as mild (Bazarian et al., 2005). Even if only a small proportion of children with mild TBI suffer persistent negative outcomes, then mild TBI is a serious public health problem.

Previous studies of the neurobehavioral outcomes of mild TBI have yielded contradictory results. On one hand, the literature provides little evidence of persistent cognitive deficits resulting from mild TBI, especially in studies that are methodologically rigorous (Asarnow et al., 1995; Carroll et al., 2004; Satz, 2001; Satz et al., 1997). On the other hand, children with mild TBI reportedly display a variety of cognitive, somatic, emotional, and behavioral problems. These problems, referred to as postconcussive symptoms (PCS), are more frequent and severe than those reported by children with injuries not involving the head, and the symptoms can persist over time in at least some individual cases (Mittenberg et al., 1997; Ponsford et al., 1999; Rivara et al., 1994; Yeates et al., 1999, in press).

Persistent PCS following mild TBI have been proposed to constitute one feature of a coherent syndrome or disorder (Brown et al., 1994; Mittenberg & Strauman, 2000). The diagnosis of postconcussion syndrome is included in the International Classification of Diseases (ICD-10; World Health Organization, 1992), and research criteria for postconcussional disorder are included in the fourth edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV; American Psychiatric Association, 1994). However, the DSM-IV and ICD-10 have different diagnostic criteria, which

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make different assumptions about the etiology of PCS, result in different incidence estimates, yield limited diagnostic agreement, and may not be specific to TBI (Boake et al., 2004, 2005; Yeates & Taylor, 2005).

One of the first steps in defining a syndrome is to determine whether and how symptoms cluster together. Several studies with adults have been undertaken to determine whether PCS form reliable clusters or dimensions (Axlerod et al., 1996; Bohnen et al., 1995; Cicerone & Kalmar, 1995; Piland et al., 2006). Despite differences in samples, rating scales, and statistical methods, the results of previous studies are generally alike in suggesting that PCS form distinct dimensions of symptoms that co-occur; moreover, the studies identified three common dimensions. The first was a cognitive factor that typically included difficulties with memory, attention and concentration, the performance of daily tasks, and decision making. The second common dimension was a somatic factor, which characteristically included symptoms such as headache, sleep disturbance, dizziness, sensitivity to noise or light, visual problems, and nausea. A third factor that emerged involved affective symptoms, such as depression, irritability, anxiety, poor frustration tolerance, and loss of motivation or apathy.

The existing literature on the structure of PCS is limited to adults. We are not aware of any published study that has focused on children. Therefore, the primary goal of the current study was to examine the dimensions of PCS in children with mild TBI, based on a sample of one hundred eighty-six 8- to 15-year-olds who were participants in a larger prospective, longitudinal study. The primary study hypotheses were that ratings of PCS in children with mild TBI would cluster into four dimensions, representing cognitive, somatic, emotional, and behavioral symptoms, and that those dimensions would remain stable across time. We anticipated the first three dimensions based on existing studies of the factor structure of PCS in adults, which have consistently identified cognitive, somatic, and emotional dimensions (Axlerod et al., 1996; Bohnen et al., 1995; Cicerone & Kalmar, 1995; Piland et al., 2006). We expected a fourth dimension, reflecting behavioral symptoms, based on previous research on neurobehavioral symptoms in moderate to severe traumatic brain injury in children (Barry et al., 1996; Yeates et al., 2001).

The secondary goal of the study was to examine parent-child agreement regarding the dimensions of PCS. Children and parents typically display only modest agreement about the presence, severity, and duration of behavioral and emotional symptoms (Achenbach, 2006; Edelbrock et al., 1986; Hodges et al., 1990). Thus, parent-child agreement regarding PCS may be relatively limited. However, few studies have examined parent-child agreement with regard to the dimensionality of symptoms, as opposed to symptom occurrence or severity. Parent and child ratings could display more agreement regarding the clustering of symptoms than about symptom presence or severity per se. The current study sought to determine the extent to which parent and child ratings of PCS would cluster into the four *a priori* dimensions described above, as well as parent-child agreement with respect to these dimensions. To the best of our knowledge, this is the first study to assess both parent and children's ratings of PCS following mild TBI.

METHOD

Participants

Participants were part of a larger prospective, longitudinal study of the neurobehavioral outcomes of mild TBI in children and adolescents (Yeates & Taylor, 2005; Yeates et al., in press). Children were recruited from the Emergency Departments at Nationwide Children's Hospital in Columbus, Ohio and Rainbow Babies and Children's Hospital in Cleveland, Ohio. All children from 8 to 15 years of age who presented for evaluation of closed-head trauma were screened to determine whether they met criteria for participation.

Children were included if they had sustained a blunt head trauma resulting in an observed loss of consciousness, or a Glasgow Coma Scale (Teasdale & Jennett, 1974) score of 13 or 14, or at least two acute signs or symptoms of concussion as noted by Emergency Department medical personnel. Acute signs and symptoms of concussion included persistent posttraumatic amnesia, transient neurological deficits, vomiting, nausea, headache, diplopia, or dizziness. Children were excluded if their injury resulted in a loss of consciousness lasting more than 30 min or if they had any Glasgow Coma Scale score less than 13. They were also excluded if they demonstrated any delayed neurological deterioration or had any medical contraindication to magnetic resonance imaging. Children were not excluded if they required hospitalization or demonstrated intracranial lesions or skull fractures on acute computerized tomography.

Children also were excluded if they met any of the following general criteria: neurosurgical or surgical intervention; any associated injury with an Abbreviated Injury Scale (AIS; American Association for Automotive Medicine, 1990) score greater than 3; any associated injury that interfered with neuropsychological testing (e.g., fracture of preferred upper extremity); hypoxia, hypotension, or shock during or following the injury; ethanol or drug ingestion involved with the injury; documented history of previous head injury requiring medical treatment; premorbid neurological disorder or mental retardation; any injury determined to be a result of child abuse or assault; or a history of severe psychiatric disorder requiring hospitalization.

Among children who met all inclusion/exclusion criteria, the participation rate was 48%. Demographic and census tract data were compiled for both participants and nonparticipants (Federal Financial Institutions Examinations Council Geocoding System, 2002). Participants and nonparticipants did not differ significantly in age, gender, or ethnic/racial minority status, or in census tract measures of socioeconomic status (i.e., mean family income, percentage of minority heads of household, and percentage of households below the poverty line).

The final sample included 186 children with a mean age of 11.96 years (*SD* = 2.22). They were 71% male and 27% ethnic or racial minority. Their socioeconomic status as rated on the Duncan Occupational Status Index (Stevens & Cho, 1985) was generally middle class (*M* = 39.04; *SD* = 18.47). Their overall injury severity as rated on the Modified Injury Severity Score (Mayer et al., 1980) was mild (*M* = 4.62; *SD* = 4.54). Within the sample, 10% had a GCS score less than 15 and 39% had an observed loss of consciousness, usually very brief in duration (median = 1 min, range = 0–15 min). Recreational and sports-related injuries were the most common cause of injury.

Procedure

Children who met all inclusion/exclusion criteria and whose parents agreed to participate were scheduled for an initial assessment no later than 3 weeks post injury, with 80% completed between 1 and 2 weeks post injury. Institutional review board approval and informed parental consent and child assent were obtained prior to participation. As part of the initial assessment, children and their parents completed measures of PCS. They did so again at 1, 3, and 12 months post injury. At the initial assessment, parents also completed a retrospective rating of preinjury symptoms, prior to rating current symptoms. For the purposes of this study, we focused on parent and child ratings obtained at the initial assessment and 3 months post injury. Of the 186 children who completed the baseline assessment, 178 or 96% also completed the assessment at 3 months post injury. Analyses were based on the total samples available at each assessment.

PCS were assessed using the Health and Behavior Inventory (HBI), which includes a variety of cognitive, somatic, emotional, and behavioral symptoms. This 50-item questionnaire requires parents and children to rate the frequency of occurrence of each symptom over the past week on a 4-point scale, ranging from "never" to "often." The parent and child forms are worded slightly differently to be age-appropriate and to reflect first- *versus* third-person perspectives (see Appendix A for parent version & Appendix B for child version). The HBI was developed based on previous research involving children with moderate to severe TBI (Barry et al., 1996; Yeates et al., 2001), as well as on a review of similar checklists used in adult studies of PCS (Axelrod et al., 1996; Cicerone & Kalmar, 1995; Gerber & Schraa, 1995; Gouvier et al., 1992). An earlier version of the HBI was used in a previous study of PCS in children with mild TBI (Yeates et al., 1999). Parents and children completed the HBI independently, out of each others' presence, by reading the items and rating each in writing; a small number of children and parents were read the HBI by research staff and responded orally because they indicated they were unable to read the questionnaire themselves.

Data Analysis

We initially examined the distribution of ratings on individual items from the HBI to identify those that demonstrated restricted variance (i.e., greater than 90% of all ratings either "never" or "often"). Two items (i.e., "has double vision," "sleepwalks") were eliminated based on that criterion. The remaining items from the HBI were subject to exploratory factor analyses as described below (Floyd & Widaman, 1995).

Both parent and child ratings were submitted to a common factor analysis using target rotation (Browne, 2001). Target rotation is similar to confirmatory factor analysis in that values for some factor loadings are specified to be 0 in advance. Unlike confirmatory factor analysis, however, loadings that are prespecified as 0 are only made to be as close to 0 as possible during the rotation, but are not held to 0. Target rotation permits incorrectly specified elements to be identified and changed; the revised target matrix can then be used in future rotations (Browne, 2001). The initial target matrix for this study was constructed by having the two principal investigators for the larger parent study (K.O.Y. and H.G.T.) assign each item to one of four potential dimensions of PCS: cognitive, somatic, emotional, and behavioral.

The agreement between child and parent factor structure was examined next. The target rotation for parent-reported PCS was examined for any incorrectly specified items. Items that did not load on the expected factors as expected (i.e., < .40) were eliminated from the original factors and moved to the factor on which they had the highest loadings. Items that had loadings below 0.40 on all factors were dropped. The refined matrix was then used as a target matrix for child-reported PCS. This entire process was then repeated, but starting instead with child-reported PCS. The child target matrix was refined, and parent-reported symptoms were rotated to that refined matrix. A final target matrix that was identical for parents and children was constructed after the process of refinement was completed separately for both parent- and child-reported symptoms. This final refined target, containing the same items for parent-reported and child-reported symptoms, allowed for an examination of configural invariance between parent-rated and child-rated symptom dimensions. In all cases, the overall adequacy of factor solutions was determined by examining the root mean squared error (RMSEA).

Additional exploratory factor analyses using oblique rotation were conducted, varying the number of factors to be extracted. Because the dimensions of PCS have yet to be examined in children, we wanted to explore whether a different number of factors (i.e., other than the four hypothesized) would better account for the interrelationships among PCS in children. Several methods for assessing the correct number of factors were used, including scree tests and examination of eigenvalues. All factor analyses were conducted using CEFA: Comprehensive Exploratory Factor Analysis (version 2) software (Browne et al., 2004)

The refined target matrix based on baseline ratings was then applied to parent and child ratings obtained 3 months post injury. The resulting factor structures were compared with those derived from baseline ratings to determine whether the pattern of factor loadings remained consistent over time for parents and children. In other words, we examined factorial invariance across time (Millsap & Meredith, 2007). Factorial invariance is typically examined using a nested sequence of models, from least restrictive to most restrictive. We focused on configural invariance, which requires the same factor structure (as opposed to specific factor loadings). Configural invariance is obtained when the zero elements of the factor solutions are in the same locations (Millsap & Meredith, 2007).

The solutions rotated to the refined target matrix were also used to examine factorial invariance between children and parents at both baseline and 3 months post injury. Again, we focused on configural invariance, which requires the same factor structure for both groups (Millsap & Meredith, 2007). Thus, child-reported and parent-reported factors were compared with determine whether the zero elements of the factor solutions were in the same locations for children and parents.

RESULTS

The initial factor analysis for parent-reported symptoms at the baseline assessment suggested a moderate fit (RMSEA = 0.09) for the four factors. After rotation to a partially specified target, examination of the rotated factor matrix suggested that several items were incorrectly specified (i.e., has a low energy level; displays poor judgment; is dependent on others; is unable to accept change; gets tired easily). These items were allowed to load on other factors. Several other items were dropped, as they did not load significantly on any of the four factors (i.e., fidgety or restless; moody; grouchy or irritable; has difficulty falling asleep; has difficulty staying asleep; experiences nightmares; does not care much about things; poor fine motor coordination; poor gross motor coordination).

The initial factor analysis for child-reported symptoms from the baseline assessment also resulted in a moderate fit (RMSEA = 0.07). After target rotation, the cognitive and somatic factor loadings were similar to those for parent-reported symptoms. The emotional factor was less robust, with only five loadings above 0.40, and the behavioral factor was poorly defined, with only two factor loadings above 0.40. The cognitive and somatic factors were refined, moving items that were incorrectly specified onto other factors (i.e., fidgety or restless; moody; difficulty falling asleep) and dropping items that did not load on either factor (i.e., difficulty finding words to express self; difficulty staying asleep; experiences nightmares; poor fine motor coordination; poor gross motor coordination). Incorrectly specified items on the emotional and behavioral factors were moved to other factors, but items with low loadings were not dropped, to preserve these factors so that consistency across raters could be evaluated.

A comparison of the refined child and parent matrices demonstrated similar cognitive and somatic factors. Thus, for the final revision of the target matrix, items that had significant loadings for both parents and children on those factors were retained. Because the factor matrix for child-reported symptoms did not demonstrate clear emotional or behavioral factors, items were retained for those dimensions based on factor loadings for parent-reported symptoms. The final factor analysis suggested moderate fit for parent-reported symptoms (RMSEA = 0.08). Table 1 shows the resulting factor loadings after target rotation for the baseline parent ratings. Correlations between the four factors ranged from $r = 0.05$ between the somatic and behavioral factors to $r = 0.45$ between the somatic and emotional factors. Correlations between the other factors were as follows: Cognitive and emotional, $r = 0.43$; cognitive and somatic, $r = 0.35$; behavioral and cognitive, $r = 0.44$; emotional and behavioral, $r = 0.28$.

The final factor analysis of child-reported symptoms demonstrated strong cognitive and somatic factor loadings, moderate loadings for the emotional factors, and low loadings for the behavioral factor. The overall fit of the model was moderate (RMSEA = 0.07). Table 2 shows the resulting factor loadings for the baseline child ratings after target rotation. Correlations between the four factors ranged from $r = 0.34$ for the somatic and behavioral factors to $r = 0.53$ for the cognitive and somatic factors. Correlations between other factors were as follows: Cognitive and somatic, $r = 0.53$; cognitive and emotional, $r = 0.50$; somatic and emotional, $r = 0.41$; emotional and behavioral, $r = 0.35$. Correlations between the child and parent factors were modest in magnitude, with only one exceeding .30; the largest correlations were between parent and child somatic factors (see Table 3).

Exploratory factor analyses with blind CF-Varimax oblique rotations were conducted for baseline symptom ratings, retaining from two to six factors. For parent ratings, a scree plot suggested retaining three or four factors. Four factors were chosen. Rotation indicated that these consisted of cognitive, somatic, emotional, and behavioral symptoms, respectively. For child ratings, a scree plot suggested retaining two factors. Rotation indicated that these consisted primarily of cognitive and somatic symptoms. Thus, the results of the exploratory analyses were generally consistent with the target rotations described above.

Using the refined target matrix from the baseline analyses, factor analyses were performed using parent and child symptom ratings at 3 months after injury. The analysis of parent-reported symptoms suggested a moderate fit (RMSEA = 0.09). Target rotation showed that cognitive, somatic, and emotional factor loadings were consistent with baseline analyses, but the behavioral factor did not produce any strong loadings (see Table 4). Correlations between the four factors ranged from −0.02 between the emotional and behavioral factors to 0.65 between the cognitive and emotional factors. Correlations between other factors were as follows: Cognitive and somatic, $r = 0.39$; cognitive and behavioral, $r = 0.09$; somatic and emotional, $r = 0.41$; somatic and behavioral, $r = 0.05$.

The analysis of child-reported symptoms also showed a moderate fit (RMSEA = 0.07), and yielded results consistent with the analyses of baseline ratings. Specifically, the cognitive and somatic factors had strong loadings, the emotional

Table 1. Refined factor matrix for parent ratings at the initial assessment

Symptom	Cognitive	Somatic	Emotional	Behavioral
Trouble sustaining attention	**0.93**	0.03	−0.04	−0.05
Easily distracted	**0.82**	0.03	−0.08	0.10
Difficulty concentrating	**0.91**	0.05	−0.02	−0.04
Problems remembering what she is told	**0.92**	0.05	−0.05	−0.05
Difficulty following directions	**0.81**	0.07	−0.02	0.07
Tends to daydream	**0.52**	−0.01	0.30	0.01
Gets confused	**0.69**	0.17	0.05	0.03
Forgetful	**0.78**	0.02	0.02	0.02
Difficulty completing tasks	**0.72**	−0.06	0.09	0.17
Poor problem-solving skills	**0.47**	−0.02	0.19	0.25
Problems learning	**0.42**	0.03	0.11	0.21
Difficulty finding words to express self	**0.40**	0.12	0.17	0.09
Low energy level	0.17	**0.48**	0.37	−0.31
Has headaches	0.20	**0.46**	0.02	0.04
Feels dizzy	−0.07	**0.79**	−0.17	0.19
Has a feeling that the room is spinning	−0.10	**0.82**	−0.12	0.23
Feels faint	−0.03	**0.78**	−0.03	0.10
Blurred vision	0.06	**0.59**	0.04	0.00
Experiences nausea	0.08	**0.64**	−0.05	−0.04
Gets tired a lot	0.09	**0.69**	0.16	−0.18
Gets tired easily	0.10	**0.64**	0.23	−0.16
Difficulty showing emotions	0.08	−0.19	**0.58**	0.10
Problems coping with change	0.14	−0.16	**0.62**	0.17
Dependent on others	0.33	0.10	**0.46**	−0.05
Unable to accept change	0.07	0.06	**0.45**	0.32
Fearful	−0.10	0.03	**0.66**	0.08
Lacks interest in interacting with others	0.02	0.16	**0.55**	−0.04
Withdrawn	0.11	0.22	**0.53**	−0.04
Acts depressed or sad	0.04	0.15	**0.56**	0.01
Seems anxious, worried, or tense	−0.11	0.22	**0.58**	0.06
Has a high activity level	0.12	−0.16	−0.07	**0.40**
Acts without thinking	0.35	−0.01	−0.06	**0.70**
Speaks without thinking	0.23	0.03	−0.06	**0.77**
Displays poor judgment	0.26	−0.17	0.21	**0.56**
Insists on doing things a certain way	−0.08	0.04	0.23	**0.55**
Sassy	−0.21	0.22	0.04	**0.51**
Physically aggressive	−0.18	0.02	0.22	**0.55**
Throws tantrums	−0.19	−0.02	0.19	**0.54**
Talks too much	0.16	0.08	−0.13	**0.60**

factor had moderate loadings, and the behavioral factor had only low loadings (see Table 5). Correlations between the four factors ranged from r = 0.02 between the behavioral and somatic factors to r = 0.64 between the cognitive and emotional factors. Correlations between other factors were as follows: Cognitive and somatic, r = 0.49; behavioral and emotional, r = 0.10; somatic and emotional, r = 0.39; cognitive and behavioral, r = 0.07. Correlations between the child and parent factors were generally small in magnitude, with only the correlation between cognitive factors exceeding .30 (see Table 6).

Thus, the cognitive and somatic factors identified based on baseline ratings showed substantial configural invariance across time for both parents and children, and the emotional factor showed moderate configural invariance across time. In contrast, the behavioral factor did not demonstrate configural invariance across time for either parents or children.

The secondary goal of the study was to compare parent-child agreement regarding the dimensions of PCS. As can be seen in Tables 1, 2, 4, and 5, parents and children demonstrated substantial configural invariance for cognitive and somatic symptom dimensions. Although absolute factor loadings tended to be lower for children, the symptoms that loaded on these two factors were highly similar for parents and children. In contrast, configural invariance was less robust for emotional and behavioral symptom dimensions. For the emotional factor, parents displayed relatively high and consistent loadings as compared with children. The behavioral factor yielded significant loadings only for parent ratings at baseline; it did not emerge for parent ratings at 3 months or for child ratings at either occasion. Despite

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Table 2. Refined factor matrix for child ratings at the initial assessment

Symptom	Cognitive	Somatic	Emotional	Behavioral
Trouble sustaining attention	**0.57**	0.15	−0.05	0.13
Easily distracted	**0.49**	−0.02	0.07	0.19
Difficulty concentrating	**0.65**	0.28	−0.24	0.10
Problems remembering what she is told	**0.46**	0.24	0.00	0.20
Difficulty following directions	**0.50**	0.09	0.14	0.17
Tends to daydream	**0.43**	0.06	0.01	0.11
Gets confused	**0.48**	0.25	0.10	0.02
Forgetful	**0.54**	0.23	0.00	0.04
Difficulty completing tasks	**0.51**	0.09	0.21	0.02
Poor problem−solving skills	**0.57**	−0.01	0.31	−0.05
Problems learning	**0.46**	0.05	0.22	0.04
Difficulty finding words to express self	**0.28**	0.03	0.32	0.14
Low energy level	0.17	**0.39**	0.09	0.10
Has headaches	0.14	**0.60**	−0.11	0.03
Feels dizzy	0.09	**0.83**	−0.08	0.05
Has a feeling that the room is spinning	−0.05	**0.78**	0.04	0.06
Feels faint	0.12	**0.63**	0.02	−0.02
Blurred vision	0.04	**0.49**	0.15	0.06
Experiences nausea	−0.11	**0.57**	0.23	−0.13
Gets tired a lot	0.31	**0.39**	0.01	−0.13
Gets tired easily	0.21	**0.37**	0.18	−0.09
Difficulty showing emotions	0.23	−0.09	**0.52**	0.09
Problems coping with change	0.10	0.11	**0.31**	0.19
Dependent on others	0.41	0.02	**0.06**	−0.04
Unable to accept change	0.34	0.07	**0.19**	0.06
Fearful	0.30	0.08	**0.25**	0.06
Lacks interest in interacting with others	−0.20	0.12	**0.85**	0.01
Withdrawn	−0.18	0.14	**0.64**	0.22
Acts depressed or sad	0.24	0.19	**0.34**	−0.05
Seems anxious, worried, or tense	0.28	0.18	**0.27**	0.01
Has a high activity level	0.23	−0.22	0.00	**0.19**
Acts without thinking	−0.02	0.01	0.13	**0.87**
Speaks without thinking	−0.02	−0.02	0.09	**0.71**
Displays poor judgment	0.26	−0.12	0.26	**0.34**
Insists on doing things a certain way	0.08	−0.06	0.24	**0.29**
Sassy	0.01	0.24	0.30	**0.16**
Physically aggressive	0.29	−0.05	0.04	**−0.06**
Throws tantrums	0.21	0.02	0.30	**0.00**
Talks too much	0.39	−0.11	0.03	**0.14**

Table 3. Factor correlations between child and parent factors for refined factor matrix at the initial assessment

	Parent factors			
Child factors	Cognitive	Somatic	Emotional	Behavioral
Cognitive	0.27	0.11	0.05	0.18
Somatic	0.29	0.39	0.16	0.12
Emotional	0.18	0.11	0.18	0.26
Behavioral	0.08	−0.03	0.07	0.04

substantial configural invariance for cognitive and somatic symptom dimensions, the correlations between child and parent factors were quite modest (see Tables 3 and 6).

DISCUSSION

The primary goal of the current study was to examine the dimensions of PCS in children with mild TBI, based on parent and child ratings. The results of factor analyses with target rotation suggest three replicable dimensions of PCS based on parent ratings, reflecting cognitive, somatic, and emotional symptoms, which emerged both at baseline and 3-months post injury. A fourth dimension representing behavioral symptoms was identified based on baseline ratings, but did not emerge from analyses based on ratings at 3-months post injury. Although we had hypothesized an additional behavioral factor based on previous research on the outcome of moderate to severe TBI in children (Barry et al., 1996; Yeates et al., 2001), the findings suggest that

Table 4. Refined factor matrix for parent ratings at the 3 month assessment

Symptom	Cognitive	Somatic	Emotional	Behavioral
Trouble sustaining attention	**0.90**	−0.01	−0.14	0.03
Easily distracted	**0.99**	0.00	−0.18	0.00
Difficulty concentrating	**0.92**	0.06	−0.09	0.00
Problems remembering what she is told	**0.85**	0.06	−0.11	0.01
Difficulty following directions	**0.86**	−0.01	−0.06	0.18
Tends to daydream	**0.57**	0.05	0.14	0.05
Gets confused	**0.67**	0.06	0.15	0.08
Forgetful	**0.71**	0.05	0.01	−0.03
Difficulty completing tasks	**0.81**	0.09	0.00	0.03
Poor problem-solving skills	**0.49**	0.13	0.28	0.11
Problems learning	**0.45**	0.19	0.23	0.03
Has difficulty finding words to express self	**0.21**	0.12	0.37	−0.02
Low energy level	0.01	**0.28**	0.39	−0.41
Has headaches	0.04	**0.39**	0.14	−0.07
Feels dizzy	−0.03	**0.83**	−0.02	0.17
Has a feeling that the room is spinning	−0.03	**0.97**	−0.18	0.27
Feels faint	−0.09	**0.98**	−0.11	0.17
Blurred vision	0.04	**0.87**	−0.14	0.15
Experiences nausea	0.00	**0.65**	0.06	0.07
Gets tired a lot	0.08	**0.60**	0.15	−0.61
Gets tired easily	0.16	**0.48**	0.20	−0.58
Difficulty showing emotions	0.06	0.12	**0.41**	−0.06
Problems coping with change	0.00	0.12	**0.69**	0.16
Dependent on others	0.26	0.04	**0.42**	0.16
Unable to accept change	0.00	0.11	**0.75**	0.15
Fearful	−0.02	0.22	**0.49**	0.20
Lacks interest in interacting with others	0.34	0.14	**0.25**	−0.13
Withdrawn	0.11	0.27	**0.34**	−0.31
Acts depressed or sad	0.16	0.08	**0.45**	0.09
Seems anxious, worried, or tense	−0.05	0.18	**0.57**	0.22
Has a high activity level	0.17	−0.02	0.24	**0.22**
Acts without thinking	0.52	−0.08	0.34	**0.08**
Speaks without thinking	0.51	−0.10	0.40	**0.12**
Displays poor judgment	0.50	0.04	0.29	**0.11**
Insists on doing things a certain way	0.14	−0.04	0.58	**0.19**
Sassy	0.16	0.12	0.42	**0.06**
Physically aggressive	0.07	0.14	0.46	**0.10**
Throws tantrums	0.35	0.05	0.23	**0.15**
Talks too much	0.39	0.14	0.19	**0.14**

behavioral symptoms are not likely to represent a consistent part of the constellation of PCS in children with mild TBI.

For child-reported symptoms, factor analyses consistently identified two dimensions of PCS, represented by cognitive and somatic symptoms, which emerged at both occasions. A third dimension, represented by emotional symptoms, may have some validity for children, although the factor loadings for that dimension were lower than those for the cognitive and somatic dimensions. A factor based on behavioral symptoms was not evident based on child ratings at either baseline or 3 months post injury, providing further evidence that behavioral symptoms do not represent a coherent grouping commonly seen after mild TBI in children.

The secondary goal of the study was to assess parent-child agreement regarding the dimensions of PCS. The cognitive and somatic dimensions were similar across parents and children, such that items with significant factor loadings for these two factors were highly similar across groups. In contrast, configural invariance across parents and children was only modest for the emotional dimension, and extremely poor for the behavioral dimension, even at baseline. These results suggest that the structure of PCS is similar for parents and children when ratings involve cognitive and somatic symptoms, somewhat less consistent for emotional symptoms, and not at all invariant for behavioral symptoms. In the future, direct tests of measurement invariance comparing children and parents on the cognitive, somatic, and possibly emotional symptom dimensions should be undertaken using confirmatory factor analyses (Millsap & Meredith, 2007).

Although the structure of PCS is similar for parents and children following mild TBI, correlations between parent and child factors were modest, with only cognitive and somatic

Table 5. Refined factor matrix for child ratings at the 3 month assessment

Symptom	Cognitive	Somatic	Emotional	Behavioral
Trouble sustaining attention	**0.67**	0.09	0.10	0.03
Easily distracted	**0.51**	0.12	0.16	0.14
Difficulty concentrating	**0.58**	0.22	0.07	0.02
Problems remembering what she is told	**0.60**	0.17	0.02	0.01
Difficulty following directions	**0.64**	−0.08	0.15	−0.04
Tends to daydream	**0.46**	0.17	−0.09	0.09
Gets confused	**0.52**	0.17	0.17	0.05
Forgetful	**0.76**	0.02	−0.08	0.00
Difficulty completing tasks	**0.52**	0.05	0.10	0.12
Poor problem-solving skills	**0.64**	0.12	0.14	−0.04
Problems learning	**0.39**	0.17	0.16	0.19
Has difficulty finding words to express self	**0.28**	0.21	0.29	−0.10
Low energy level	0.23	**0.31**	−0.05	0.30
Has headaches	−0.09	**0.61**	0.08	0.04
Feels dizzy	−0.10	**0.98**	−0.10	−0.04
Has a feeling that the room is spinning	−0.15	**0.94**	−0.08	−0.07
Feels faint	−0.18	**0.82**	0.12	−0.09
Blurred vision	0.24	**0.45**	0.05	0.04
Experiences nausea	0.11	**0.46**	0.18	0.00
Gets tired a lot	0.34	**0.38**	0.02	0.03
Gets tired easily	0.30	**0.42**	0.00	0.02
Difficulty showing emotions	0.19	0.17	**0.43**	−0.03
Problems coping with change	0.00	0.10	**0.76**	−0.46
Dependent on others	0.28	0.27	**0.19**	−0.10
Unable to accept change	0.02	−0.06	**0.81**	−0.44
Fearful	0.33	0.14	**0.22**	−0.01
Lacks interest in interacting with others	−0.19	0.07	**0.72**	0.39
Withdrawn	−0.25	−0.02	**0.86**	0.64
Acts depressed or sad	0.28	0.10	**0.33**	−0.08
Seems anxious, worried, or tense	0.18	0.07	**0.43**	0.05
Has a high activity level	0.00	−0.02	0.14	**−0.16**
Acts without thinking	0.18	−0.04	0.40	**0.05**
Speaks without thinking	0.32	−0.07	0.27	**0.06**
Displays poor judgment	0.42	−0.08	0.30	**0.02**
Insists on doing things a certain way	0.17	0.01	0.42	**0.06**
Sassy	0.49	0.08	0.06	**0.14**
Physically aggressive	0.40	0.02	0.07	**0.23**
Throws tantrums	0.38	0.00	0.20	**0.02**
Talks too much	0.21	0.00	0.21	**−0.03**

Table 6. Factor correlations between child and parent factors for refined factor matrix at the 3 month assessment

	Parent factors			
Child factors	Cognitive	Somatic	Emotional	Behavioral
Cognitive	0.31	0.11	0.13	−0.10
Somatic	0.10	0.07	0.02	−0.13
Emotional	0.21	0.07	0.22	0.01
Behavioral	−0.11	0.06	−0.05	−0.07

factors demonstrating moderate correlations. Future research will be needed to determine whether parents and children agree on the occurrence or severity of PCS, as opposed to their dimensional structure. Based on the existing literature on cross-informant agreement (Achenbach, 2006; Edelbrock et al., 1986; Hodges et al., 1990), only moderate concordance is likely between parent and child symptom reports, consistent with the modest correlations between child and parent factors found here.

The symptom dimensions identified in this study are similar in many respects to those found in studies of adults who have sustained mild TBI (Axlerod et al., 1996; Bohnen et al., 1995; Cicerone & Kalmar, 1995; Piland et al., 2006). We believe this is the first published study to examine the structure of PCS in children with mild TBI. Thus, the findings replicate and extend previous research on the dimensions of PCS by suggesting that cognitive, somatic, and emotional symptom dimensions are also characteristic of children with mild TBI, whether rated by parents or by the children themselves.

The cognitive, somatic, and emotional dimensions that emerged in this study, as well as in studies of adults of mild TBI, include many of the symptoms listed in the ICD-10 diagnostic criteria for Post-Concussion Syndrome (World Health Organization, 1992) and the DSM-IV research criteria for Post-Concussive Disorder (American Psychiatric Association, 1994). As noted earlier, however, the DSM-IV and ICD-10 have different diagnostic criteria, including partially overlapping lists of PCS, the validity of which is uncertain (Boake et al., 2004, 2005; Yeates & Taylor, 2005). The current findings, together with the past literature, set the stage for possible refinements of the ICD-10 and DSM-IV criteria, by identifying replicable and distinct dimensions of symptoms that may arise following mild TBI. The research to date suggests that diagnostic criteria for postconcussive syndrome should refer to specific dimensions of symptoms (i.e., somatic, cognitive, emotional) derived from empirical, factor analytic studies, rather than to a generic list of individual symptoms.

One potential limitation of the current study is the sample size. A participant-to-variable ratio of 5:1 is often considered to be the minimum needed to conduct a valid factor analysis (Gorsuch, 1983). The current sample size falls a bit short on that score. However, traditional guidelines regarding participant-to-variables ratio are not statistically defensible (Fabrigar et al., 1999; Floyd & Widaman, 1995). Recent research indicates that an adequate sample size for factor analysis depends on the communalities of measured variables and the number of variables with substantial loadings per factor, rather than on the number of variables per se (Guadagnoli & Velicer, 1988; MacCallum et al., 1999; Velicer & Fava, 1998). When communalties are relatively high and factors are overdetermined (i.e., represented by at least three or four variables), accurate parameter estimates can be obtained with samples as small as 100. Based on the magnitude of communalities for individual items and overdetermination of most factors in the analyses reported in this study, we believe the current sample is sufficiently large to yield valid findings. Nonetheless, the results should be replicated in other samples.

The current findings do not directly address the ongoing controversy regarding the outcomes of mild TBI in children. The inconsistency between studies using standardized cognitive testing as opposed to subjective symptom reports to assess outcomes remains a major source of debate in the scientific literature regarding TBI (Yeates & Taylor, 2005). Future research is needed to examine whether children with mild TBI demonstrate more PCS than children with injuries not involving the head or healthy children and whether any differences between groups persist over time. Notably, the current findings suggest the need to examine specific dimensions of PCS, which could be differentially sensitive to the effects of mild TBI and show different time courses post injury.

The identification of specific dimensions of PCS may also help to quell the ongoing controversy regarding the determinants of those symptoms, often framed in terms of "psychogenesis *versus* physiogenesis" (Alexander, 1997; Lishman, 1988). Research with children and adults indicates that both injury characteristics and noninjury related variables help explain outcomes following mild TBI, with noninjury related variables often accounting for relatively more variance (Luis et al., 2003; Ponsford et al., 1999, 2000). However, the contributions of injury characteristics and noninjury related factors may well vary as a function of both symptom type and time post injury. In a previous study of children with moderate to severe TBI, we showed that different symptom types were related in distinct ways to injury and noninjury related risk factors at different intervals following injury (Yeates et al., 2001). For instance, post-injury parent and family adjustment predicted emotional and behavioral symptoms but not cognitive and somatic symptoms, and injury severity was a stronger predictor of cognitive and somatic symptoms immediately post injury than later during recovery. The current results suggest that future research should examine specific dimensions of PCS over time when attempting to determine the relative contributions of injury characteristics and noninjury related variables as predictors of PCS following mild TBI in children. In the future, we intend to present analyses along these lines, based on the larger parent study that served as the basis for this study.

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APPENDIX A

Parent Version of Health and Behavior Inventory

Directions: Below is a list of problems that your child may or may not have. For each problem, please rate your child based *on the last week* using the scale below.

	O = Never,	1 = Rarely,	2 = Sometimes,	3 = Often
1. has trouble sustaining attention	0	1	2	3
2. is easily distracted	0	1	2	3
3. has difficulty concentrating	0	1	2	3
4. has problems remembering what he/she is told	0	1	2	3
5. has difficulty following directions	0	1	2	3
6. tends to daydream	0	1	2	3
7. gets confused	0	1	2	3
8. is forgetful	0	1	2	3
9. has difficulty completing tasks	0	1	2	3
10. has a high activity level	0	1	2	3
11. is fidgety or restless	0	1	2	3
12. has a low energy level	0	1	2	3
13. acts without thinking	0	1	2	3
14. speaks out without thinking	0	1	2	3
15. has difficulty showing emotions	0	1	2	3
16. has problems coping with change	0	1	2	3
17. displays poor judgment	0	1	2	3
18. has poor problem-solving skills	0	1	2	3
19. is dependent on others	0	1	2	3
20. insists on doing things a certain way	0	1	2	3
21. is unable to accept change	0	1	2	3
22. is fearful	0	1	2	3
23. lacks interest in interacting with others	0	1	2	3
24. has problems learning	0	1	2	3
25. is withdrawn	0	1	2	3
26. is “sassy”	0	1	2	3
27. is physically aggressive	0	1	2	3
28. throws tantrums	0	1	2	3
29. is moody	0	1	2	3
30. talks too much	0	1	2	3
31. acts depressed or sad	0	1	2	3
32. seems anxious, worried, or tense	0	1	2	3
33. has headaches	0	1	2	3
34. feels dizzy	0	1	2	3
35. has a feeling that the room is spinning	0	1	2	3
36. feels faint	0	1	2	3
37. has blurred vision	0	1	2	3
38. has double vision	0	1	2	3
39. experiences nausea	0	1	2	3
40. gets tired a lot	0	1	2	3
41. has difficulty falling asleep	0	1	2	3
42. has difficulty staying asleep	0	1	2	3
43. experiences nightmares	0	1	2	3
44. sleepwalks	0	1	2	3
45. has difficulty finding words to express self	0	1	2	3
46. doesn’t care much about things	0	1	2	3
47. is grouchy or irritable	0	1	2	3
48. gets tired easily	0	1	2	3
49. has poor fine motor coordination (e.g., difficulty holding on to objects, writing)	0	1	2	3
50. has poor gross motor coordination (e.g., difficulty running, jumping, catching)	0	1	2	3

APPENDIX B

Child Version of Health and Behavior Inventory

Directions: Below is a list of problems you may or may not have. For each problem, please rate yourself using the scale below *based on the last week*.

	O = Never,	1 = Rarely,	2 = Sometimes,	3 = Often
1. I have trouble paying attention	0	1	2	3
2. I get distracted easily	0	1	2	3
3. I have a hard time concentrating	0	1	2	3
4. I have problems remembering what people tell me	0	1	2	3
5. I have problems following directions	0	1	2	3
6. I daydream too much	0	1	2	3
7. I get confused	0	1	2	3
8. I forget things	0	1	2	3
9. I have problems finishing things	0	1	2	3
10. I am “always on the go”	0	1	2	3
11. I can’t sit still for long	0	1	2	3
12. I don’t have a lot of energy	0	1	2	3
13. I *do* things before I think about it	0	1	2	3
14. I *say* things before I think about it	0	1	2	3
15. I have problems showing how I feel	0	1	2	3
16. I don’t like it when changes happen	0	1	2	3
17. I make bad choices	0	1	2	3
18. I have trouble figuring things out	0	1	2	3
19. I ask for help from people a lot	0	1	2	3
20. I like to do things only one way	0	1	2	3
21. I don’t like it when things change	0	1	2	3
22. I get scared	0	1	2	3
23. I don’t like to be around other people	0	1	2	3
24. It’s hard for me to learn new things	0	1	2	3
25. I don’t like to be with other people	0	1	2	3
26. I am “sassy” with people	0	1	2	3
27. I hit, kick, or bite other people	0	1	2	3
28. I throw tantrums	0	1	2	3
29. My mood changes a lot	0	1	2	3
30. I talk a lot	0	1	2	3
31. I am sad	0	1	2	3
32. I worry and get nervous	0	1	2	3
33. I have headaches	0	1	2	3
34. I feel dizzy	0	1	2	3
35. I feel like the room is spinning	0	1	2	3
36. I feel like I’m going to faint	0	1	2	3
37. Things are blurry when I look at them	0	1	2	3
38. I see double	0	1	2	3
39. I feel sick to my stomach	0	1	2	3
40 I get tired a lot	0	1	2	3
41. I have problems falling asleep	0	1	2	3
42. I have problems staying asleep	0	1	2	3
43. I have nightmares or bad dreams	0	1	2	3
44. I sleepwalk	0	1	2	3
45. I have a hard time saying what I mean	0	1	2	3
46. I don’t care much about things	0	1	2	3
47. I am too grouchy or cranky	0	1	2	3
48. I get tired easily	0	1	2	3
49. I have trouble doing things like writing and cutting with scissors	0	1	2	3
50. I have trouble doing things like running, jumping, and catching	0	1	2	3