THESIS

PEDIATRIC TRAUMATIC BRAIN INJURY AND EDUCATIONAL IDENTIFICATION: ESTIMATING INJURY SEVERITY USING DATA FROM A TBI SCREENING TOOL

Submitted by

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ABSTRACT

PEDIATRIC TRAUMATIC BRAIN INJURY AND EDUCATIONAL IDENTIFICATION:
ESTIMATING INJURY SEVERITY USING DATA FROM A TBI SCREENING TOOL

Traumatic brain injury is a significant source of disability in children and its sequelae can significantly impact a child's academic abilities and school success. Only a small percentage of children who sustain a TBI, however, will receive academic supports specific to TBI, whether through an IEP, 504 plan, or Response to Intervention. The *Brain Check Survey* (BCS) is a parent-report screening tool designed to be used in educational settings to screen for past incidents that may have caused brain injuries as well as for behaviors and symptoms that may be related to a past TBI and that are impacting a specific student's school performance. In the state of Colorado, having a parent complete the BCS is one of the steps used to determine if a child has a "credible history" of brain injury that is necessary to qualify the child for services. As of yet, however, there are no guidelines given for how to interpret the portion of the BCS that inquires about past incidents that may have caused a brain injury. The purpose of this study was to develop a model for interpreting this portion of the BCS and for roughly estimating the severity of any of the student's past head-related injuries. An Injury-Severity Classification Model (ISCM) was developed and inter-rater reliability tested for its use. Data from completed BCS forms collected in five different Colorado school districts were used for analysis. Additionally, preliminary testing of the model's construct validity was conducted using the resulting severity groups and their presenting behaviors and symptoms as reported on the BCS. High inter-rater reliability was established for the ISCM and its utility was demonstrated for estimating past injury severity among students already identified as having sustained a TBI and receiving services, as well as among students currently receiving no special services. Recommendations are made for revisions of the Injury-Severity Classification Model (ISCM) and for future research.

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Literature Review

Traumatic Brain Injury (TBI) in children has been called a "silent epidemic" with significant consequences, including potential death or disability (Chapman et al., 2010; Graham, 2001; Tonks, Williams, Yates, & Slater, 2011). Currently over 500,000 children aged 0-14 per year sustain a TBI requiring an emergency room visit or hospitalization (Faul, Xu, Wald, & Coronado, 2010). Children aged 0-4 and youth aged 15-19 years make up the two groups with the highest numbers of TBI-related emergency department visits, as reported by the Centers for Disease Control (Faul et al., 2010). Beyond these recorded data, there are an unknown number of additional children and adolescents who sustain TBI each year, who neither receive medical care nor are diagnosed with a TBI (Faul et al., 2010; Halldorsson et al., 2012; Hooper et al., 2004). Some estimates of TBI-induced disability in children reach as high as 29,000 incidents per year (Glang, Tyler, Pearson, Todis, & Morvant, 2008), although the CDC cautions that it is difficult to accurately estimate this number (Faul et al., 2010).

The effects of TBI are varied and dependent on multiple factors. A TBI can affect a child's cognitive, neuropsychological, emotional, behavioral, adaptive, and social skills, as well as his or her overall quality of life (Anderson et al., 2009; Catroppa, Anderson, Morse, Haritou, & Rosenfeld, 2007; Fay et al., 2009; Rivara et al., 2011; Tonks et al., 2011). Factors associated with these outcomes include a child's initial score on the Glasgow Coma Scale, length of post-traumatic amnesia, extent of brain damage as displayed by radiological tests, cause of injury, premorbid levels of functioning, and family functioning before and after the event (Catroppa et al., 2007; Kriel, Krach, Luxenberg, Jones-Seate, & Sanchez, 1994; Levac, Dematteo, Hanna, & Wishart, 2008).

Recovery from a TBI can vary and while many children may recover well, there are also many who can face significant long-term challenges. Hooper et al. (2004) found in a study of 681 children who received medical care following a TBI that 25.4% of the sample experienced at least one remaining neurological, cognitive, or behavioral symptom at a 10 month follow up assessment. Rivara et al. (2011) reported on disability in children three, 12, and 24 months after a TBI and found that children with mild TBI without intracranial hemorrhage experienced initial decreases of functioning constituting disability, but showed improvement at 24 months. In contrast, the children from the same study who had a moderate or severe TBI experienced continued deficits in communication, self care, and social participation that were significantly greater than their peers. Fay et al. (2009) studied longitudinal outcomes of children with TBI, and found that 40% of children with a severe TBI had functional deficits four years post injury in neuropsychological, behavioral, adaptive, and/or academic domains. Thus a TBI can be a life changing event that can have an impact throughout childhood and potentially have lifelong implications.

Not only can children experience long term effects from a TBI, but these TBI-related challenges can affect their functioning in school. Experiencing a TBI can result in school absenteeism, sometimes up to 10 months long, which in itself can set a child behind (Hooper et al., 2004; Ylvisaker & Feeney, 1998). Behavioral problems in children, after sustaining TBI, can range from impulsivity and attention deficits to aggression and poor social skills. These behavioral changes clearly can impact a child's ability to learn and participate in school functions (Chapman et al., 2010; Fay et al., 2009; Max, Robertson, & Lansing, 2001). Children's cognitive abilities, academic abilities, and executive functioning also can be affected negatively by a TBI (Anderson et al., 2009; Chapman, et al., 2010; Ewing-Cobbs et al., 2006, Mangeot, Armstrong, Colvin, Yeates, & Taylor, 2002). Ewing-Cobbs et al. (2006) reported that from their study of 23 children with TBI, nearly half failed a school grade and/or needed special education services. Areas such as memory, reading, math, language, visual-spatial reasoning, and problem-solving are examples of brain functions that can be especially impacted among children with TBI (Anderson et al., 2009; Ewing-Cobbs et al., 2006). Thus, the effects of TBI can put children at risk for difficulties in school, due to both cognitive and behavioral challenges.

Since TBI can have profound effects on a child's ability to do well in school, it is important that educators understand these effects and the factors associated with them. Severity of injury is well established as a factor influencing outcomes after a TBI. Children who have sustained a severe or moderate TBI tend to show significant deficits in intellectual abilities, attention, processing speeds, executive functioning, and academic achievement (Catroppa et al., 2007; Chapman et al., 2010; Ewing-Cobbs et al., 2006). A meta-analysis of 18 publications conducted by Vu, Babikian, and Asarnow (2011) found that children who had sustained a moderate TBI experience impairments in academic skills following the injury that persisted over time. Those children with severe TBI had significant impairments in language, as well as academic abilities, and specifically demonstrated poorer functioning in reading and language abilities than children with moderate injuries. A meta-analysis of 28 publications conducted by Babikian and Asarnow (2009), found that children with moderate TBI experience persistent deficits in several neurocognitive domains, especially in the skills related to attention and executive functions and in general intelligence. Children with severe TBI showed impairments in all of the neurocognitive domains (general intelligence, attention and executive function, memory, and perceptual) (Babikian & Asarnow, 2009). Additional studies have reported that children with severe injuries are more likely to develop personality changes and externalizing behaviors than children with mild or moderate TBI (Chapman et al., 2010; Max et al., 2001). Effects of a moderate or severe TBI therefore can affect a variety of functions and abilities in children that can have considerable impacts on a child's functioning in school.

The effects of mild TBI are much harder to generalize or to predict. Meta-analyses have shown that children with mild TBI show no significant deficits in academic or language abilities over time, when compared to children without brain injury, and display few neurocognitive deficits (Babikian & Asarnow, 2009; Vu et al., 2011). Anderson, Catroppa, Haritou, Morse, and Rosenfeld (2005), found that at 30 months post injury, children with mild TBI showed no significant effects in physical, intellectual, memory, attention, or behavioral functions. Some individual studies, however, have found long-term deficits in children with mild TBI. In one study, although children with a mild TBI showed no significant differences in quality of life or in behaviors, 30% did show cognitive impairment three months after injury, when compared to normative populations (Petersen, Scherwath, Fink, & Koch, 2008). Furthermore, children with mild injuries may experience symptoms such as headaches, memory and attention problems, depression, anxiety, and decreased tolerance for frustration, months after the TBI (Hooper et al., 2004). One longitudinal study found that children who sustained a mild TBI before the age of four and were hospitalized for it, displayed significantly more behavioral problems between ages seven to thirteen, than both a cohort group who did not have any record of a head injury and a group of children with mild TBI who received only outpatient care (McKinlay, Grace, Horwood, Fergusson, & MacFarlane, 2008). Several researchers have suggested that the cases of long term deficits in children with mild TBI may be due to a younger age at injury during times when the brain may be undergoing processes that make it especially vulnerable to injury or illness (Anderson et al., 2009; Babikian & Asarnow, 2009; McKinlay et al., 2008). Another suggestion made is that there can be a wide range of severity encompassed by a classification of mild TBI, due to variations in classification methods or incorrect diagnoses (Babikian & Asarnow, 2009; McKinlay et al., 2008). This leads to a varied group that includes some children who had injuries significant enough to cause long term deficits. Thus, it is apparent that the potential for adverse consequences exists across the range of TBI diagnoses that can affect a child's performance and success in school.

With the extent of potential long term deficits following injury, children who have sustained a TBI, especially those which were classified as severe or moderate, may need school-based services to facilitate their academic success. According to the U.S. Department of Education in 2008-2009, 26,000 children with TBI were receiving support under the Individuals with Disabilities Education Act, Part B (IDEA) (U.S. Department of Education, 2011). Since over 35,000 children (ages 0-14) per year are hospitalized for a TBI, and since multiple studies show that hospitalized children tend to have more and longer-lasting challenges than their peers, it is likely that many of these hospitalized children will need educational support (Chapman et al., 2010; Faul et al., 2010; Fay et al., 2009; Hooper et al., 2004; McKinlay et al., 2008). Even so, an examination the U.S. Department of Education's statistics for the number of children served under IDEA per year suggests that since 2001, an average of less than 1,000 additional children each year are identified for services (U.S. Department of Education, 2011). While some children may receive support in other ways not included in these numbers, such as through Response to Intervention (RTI) or a 504 plan, the disparity of the children who likely will need services and those actually receiving them continues to remain great. This disparity has been specifically recognized by the Colorado Department of Education, which reports that there are just under 500 students in the state who currently have an IEP under the TBI category, but that there are 2,392 children each year who are discharged from a hospital after having sustained a TBI (Colorado Department of Education, 2013). Clearly, there are an unknown number of children who have sustained a TBI and may be in need of educational support, but who are left either unidentified, under-served, or are possibly being served under an inappropriate special education classification.

As seen above, a diagnosis of TBI does not mean that the child needs special services. If, however, the child does need special education services, there is no guarantee at this time that the child will receive the services he/she might need most. There are many factors that influence the likelihood of receiving services. According to a study reported by Glang and colleagues (2008), one such factor was the severity of injury, with children with more severe TBI's having higher rates of receiving educational support. Parental education about TBI is another important factor. The provision of information to parents about potential long-term effects of a TBI, as well as how to access support for their children from schools, was found to be related (indirectly or directly), to children's eventual service status in schools (Dettmer, Daunhauer, Detmar-Hanna, & Sample, 2007; Glang et al., 2008; Hooper et al. 2004). Unfortunately, many families receive neither information nor support from hospital staff to assist in transitioning children from the hospital to their home and eventually to their return back to school. In the study by Glang et al. (2008), half of the parents of children who had been hospitalized at least over night for a TBI, reported that they received no transitional support from hospital staff.

Another reason that children may not receive proper identification for services is that the need for services may not arise until years later. For many children, this is the case as patterns of deficits emerge as the child develops and increasingly needs to draw upon higher level cognitive and behavioral skills. These skills may rely on brain functions that were impaired permanently when his/her TBI was sustained, but as they were not required at the time, they were also not observed to have been effected (Anderson et al., 2005; Glang et al., 2008; McKinlay et al., 2008). If a child does not receive services initially, the likelihood of initiation of services later is low, even if academic or behavioral challenges related to the TBI develop (Dettmer, et al., 2007; Glang, et al., 2008; Taylor, et al, 2003). Conversely, emerging problems may be mislabeled as learning disorders, behavioral disorders, emotional challenges, or simply a lack of motivation (Dettmer et al., 2007; Glang et al., 2004; Hawley, 2005; McKinlay et al., 2008; Ylvisaker & Feeney, 1998). Effects of TBI produce unique skill sets and patterns of improvement that are unique from the above disorders and therefore children need services specific to TBI (Colorado Department of Education [CDE], 2013; Ylvisaker & Feeney, 1998).

Another reason that children may not receive appropriate services is that they may never have received an appropriate diagnosis for TBI to begin with. This may be because they did not receive medical care; but unfortunately, it appears that sometimes TBI is under-diagnosed even when the child is seen by medical professionals. In a study by Powell, Ferraro, Dikmen, Temkin, and Bell (2008), researchers followed a protocol to diagnose mild TBI in emergency departments and these were then compared with patients' official medical records. They found that 56% of the mild TBI cases that the research personnel identified did not have mild-TBI related diagnoses in their medical record. A myriad of explanations and research findings demonstrate that many children with TBI may need services to support their success in school, but they, their parents, and many educators are unaware of their needs or unable to advocate for the appropriate services.

Ultimately, it is important to understand what factors affect a child's success in school in order to build a strong foundation for his/her eventual transition out of school to employment and/or postsecondary education. Todis and Glang (2008) conducted a qualitative study to explore the factors related to postsecondary transition outcomes in youth after a TBI. They found that one-fourth of their sample did not receive special education services, and of that fourth only half received any help preparing specifically for transition out of high school and on to employment or further education. Overall, Todis and Glang (2008) provided evidence that support services are needed to help students with TBI identify goals, develop life skills, and get connected with support in either vocational or postsecondary education. Sadly, this is all the more important, since childhood TBI is associated with higher incidences of violent crime, mental health disorders, and poor academic success in adulthood (Leon-Carrion & Ramos, 2003; Tonks et al., 2011). It becomes imperative for these children and youth, that schools educate their faculty and staff about the unique needs of children with TBI, and then aggressively seek out those students who are struggling in school, possibly due to effects of a TBI.

A final reason that students with TBI may not receive proper services, is the lack of satisfactory methods for identifying students who are in need of services. While TBI is officially recognized as a disability category under IDEA, not only do the specific requirements to prove eligibility differ by state, but there are not always proactive ways to identify students in need of assessment (CDE, 2013; Glang et al., 2004;). Furthermore, many teachers report a lack of education and training in identifying and providing help for children with TBI (Glang et al., 2008). Numerous researchers and authors have pointed out the need for tools to screen students for on-going and emerging challenges due to a TBI (Dettmer et al., 2007; Glang et al., 2008; Sesma, Slomine, Ding, McCarthy, & the Children's Health After Trauma Study Group, 2008; Ylvisaker & Feeney, 1998). While some assessment tools do exist, such as the Brain Injury Screening Questionnaire, the Columbus Public Schools Brain Injury Screen, and the Brain Injury

Alert, these either are expensive, time consuming, require specialized training, or do not have published studies of their validity and reliability (Pickle, 2013). Glang et al. (2008) suggested that if better assessment tools for identifying TBI were made available in the schools, more students' actual disabling condition would be identified accurately, and they then could obtain the support services their special needs require.

Recognizing this need for better assessment tools, Dettmer et al. (2007), created the *Screening Tool for Identification of Acquired Brain Injury in School-Aged Children* (STI), which was revised in 2009 and renamed the *Brain Check Survey* (BCS). As an educational tool intended be used as an initial screening in schools, the BCS approaches the identification of a TBI from a pragmatic perspective: Has a past event involving potential damage to the brain occurred, and is the child experiencing behaviors or symptoms that may be due to such an event? The BCS contains six sections including basic student demographics, past injuries or illnesses, behaviors that affect learning, TBI-related symptoms, educational services, and family information. The section on past injuries and illnesses covers multiple categories of brain injury including traumatic injuries (defined as those that are caused by an external blow or force on the head) as well as non-traumatic injuries (such as those that occur due to an illness, anoxia, or seizures). For each category of injury or illness, information related to the incident is gathered, including the occurrence of a concussion, loss of consciousness, coma, confusion or altered mental state, and missed school. The appendix contains the complete version of the *Brain Check Survey*.

Under the Colorado Department of Education and Colorado's Traumatic Brain Injury Networking Team's collaboratively-designed protocol for identifying TBI in educational settings, completing the BCS is situated as one of the routes parents can take to confirm a "credible history" of a past TBI (CDE, 2013). At this point, however, there is not a systematic method for the "Injuries and illnesses" section of the BCS to be interpreted or categorized in order to understand if the information provided by the parent(s) about an incident can be interpreted as a "credible history." The purpose of this study was to develop a model that could guide educators and other professionals using the BCS in interpreting whether the information reported in the "Injuries or Illnesses" component of the BCS indicates credible past brain injury/ies, and if so, provide a rough estimate of injury severity. Incorporating the injury severity model's estimation procedure may facilitate better discussion amongst the educational teams and parents, as well as and future research teams, by giving them a guide and common language to use both in screening students for possible brain injury and for future planning. The research questions that guided this study were the following:

1) Is it feasible that a brain injury classification model could be developed that uses parents' answers on the "Injuries and Illnesses" section of the Brain Check Survey to determine the severity level of injuries or illnesses experienced by the student?

2) By following the guidelines for such a brain injury classification model, can substantial (≥.60) inter-rater reliability (Sim & Wright, 2005), be obtained between independent raters?

3) Do the severity classifications determined by this model correspond with what might be expected when compared with the child's current functioning as reported on the BCS?

Methods

Design

The current study explored a method of interpreting the "Injuries or Illnesses" component of the *Brain Check Survey* (BCS) by creating a model to classify reported incidents by severity. The model was based on research literature, with the goal of contributing to examination of the BCS screening tool's construct validity. A preliminary testing of the model was conducted to determine inter-rater reliability. Exploratory analysis additionally was conducted into whether the severity levels determined by the model tend to correspond with the behaviors and symptoms scores reported on the BCS and/or with the known school-service status of the child. Revisions and testing of the BCS were initially studied during a project funded by the Colorado Traumatic Brain Injury Trust Fund in 2009-2011, which collected 545 completed *Brain Check Survey* questionnaires. As a continuation of the tool testing process, the data from that project were used for this study as well. The reliability and validity research of the BCS was approved by the Colorado State University Human Research Committee, and by the ethics committees of each of the five participating school districts.

Participants

Sampling for the 2009-2011 research project included three different groups: 1) students considered typically-developing and who did not have an Individualized Educational Plan (IEP) or 504 plan (TYP), 2) children with known TBI, who were receiving special education services for TBI (TBI), and 3) children receiving special education for specific learning disabilities (SLD). Five different school districts in Colorado of various sizes participated. Stratified random sampling was conducted for the TYP group so that the number of participants recruited from each district was proportional to each school district's size, so that an equal number of males and females were recruited, and so that an equal number of students in the three school levels (elementary, middle, and high school) were recruited. Whole group convenience sampling was conducted for the TBI group, due to low numbers of students with that special education categorization in all five school districts. Finally, the SLD group was recruited using the same multiply-stratified sampling process used with the TYP group, with the difference that the selection sample mirrored the size of the known TBI group in each district. Parents of the selected students from each district were the actual target participants for our study, since the BCS is a parent-report questionnaire. None of the students selected by each district were ever contacted by project staff, since the parents served as informants about the selected students. A total of 545 completed BCS forms were returned to the project office, including 51 with known (TBI), 34 with learning disabilities (SLD), and 460 children considered typical (TYP). The final response rate, including completed BCS forms from all five districts, was 43.86% for the TBI group, 28.13% for the TYP group, 22.67% for the SLD group, and 28.79% overall.

The Instrument

The *Brain Check Survey* has undergone testing of its reliability and validity through various revisions of the tool over the past decade. Content validity was established during a pilot study for an early version of the BCS, formerly called the *Screening Tool for Identification of Acquired Brain Injury in School-Aged Children* (STI), through extensive research on the developers' part, as well as a series of formal discussions with an expert panel of researchers in the field of pediatric TBI (Dettmer et al., 2007). Test-retest reliability in that pilot study was determined by requesting that parents of the students with TBI, who participated in that study (n=20), to agree to a second round of completing the STI, one month later. Results for the test-re-test reliability analysis of scores on the completed BCS for behaviors, injuries, and symptoms were: $r_s = 0.85$, $r_s = 0.70$, and $r_s = 0.60$ respectively (Dettmer et al., 2007). Another reliability test of the BCS examined its internal consistency, which showed results of: $r_s = 0.95$ for behaviors, $r_s = 0.98$ for symptoms, and $r_s = 0.63$ for injuries. Furthermore, through the initial pilot study as well as the recent 2009-2011 project, it has been shown that the BSC can discriminate between children with brain injury, SLD and TYP children in injuries reported; between children in the TBI group and TYP children in total scores of reported behaviors and symptoms; and between the TBI group and SLD students in total scores of reported behaviors (Sample, Daunhauer, & Dettmer, 2011). The most recent study, a factor analysis, obtained additional evidence of the construct validity of the behaviors and symptoms components of the BCS (Pickle, 2013).

Procedures

Packets containing information about the BCS, the study, consent forms (TBI and SLD groups) or information sheet (TYP group), the survey itself (which was given a coded number, in lieu of containing the parent or child's name), a stipend reimbursement form, and a stamped return envelope were mailed out to parents/guardians of all recruited students from the five school districts. A reminder mailing, which included all of the same items was then sent out two weeks later. Returned surveys, signed consent forms (from the parents of participants in the TBI and SLD groups), and completed stipend reimbursement forms were separated by one project staff member immediately upon being opened, to ensure confidentiality of information, and all three items were then stored in separate locked file drawers. Parents of children with an identified TBI were contacted by each district's designated "TBI specialist," in order to encourage them to complete and return their survey forms. All data from each completed BCS form were inputted into the BCS study database by various members of the study staff.

Periodically, a quality control examination would be conducted by another researcher, to ensure that the information from the completed BCS forms was being entered correctly and thoroughly.

Data Analysis

In this current study, inter-rater reliability of the model develop to classify severity of injuries reported on the BCS was determined using the Kappa statistic. This statistic is especially useful for determining the extent to which agreement is found between raters, beyond that which would occur by chance (Sim & Wright, 2005). The non-weighted Kappa was used as the classification categories were treated as nominal data. Specifically, inter-rater reliability of the classification model was established by rating twenty randomly selected participants from the TBI group. As part of the purpose of the BCS is to be able to identify children whose history suggest they sustained a TBI, but who do not yet have an IEP and who may benefit from one to address TBI related challenges, we also wanted to test the model's ability to classify children and youth in the TYP group who had a history of injury or illness. To do this, we separated the group into those students whose parents did not report any injuries or illnesses on the BCS and those whose parent had reported at least one injury or illness, with this latter group becoming a Typical-with-a-history group (TypHx). Twenty participants were randomly selected from TypHx group for classification. The TBI and TypHx groups were independently rated by the researcher and her thesis advisor, and the percent agreement, Kappa, and Kappa-related *z*-score were computed.

Exploratory analysis of the model's ability to estimate severity of past injuries or illnesses was conducted in two ways. The first was to classify all the participants in the TBI group. As the literature has shown that the likelihood of receiving services is greater with increasing severity of injuries, it seemed safe to expect that a majority of the students in the known TBI group would classify as having sustained moderate or severe injuries. Additionally, a subsample of participants in the TypHx group also was classified. Here, it seemed appropriate to suspect that the majority of classifications in the TypHx group would be considered less severe injuries, as these students have not been identified for services. Thus, the model would be shown to be valid, if it indeed classified participants in the known TBI group as having had more severe injuries and the participants in the TypHx group as having less severe injuries.

A second way that the validity of the injury classification model was explored was through determining if the students sorted into the resulting TBI injury severity groups (Mild, Moderate, and Severe) score differently on three components or subtests of the BCS (symptoms, behavioral control, and cognitive processing). The TBI severity groups also were compared to the TypHx severity groups based on the subtest scores. An ANOVA was conducted comparing the resulting injury severity groups with the dependent variables being the scores in each of the three subtests of the BCS, which have been developed through factor analysis: Symptoms, Behavioral Control, and Cognitive Processing (Pickle, 2013). See Table 1 for the list of BCS questions that fall into each of the three factors.

Table 1

BCS Items in the Symptoms, Behavioral Control, and Cognitive Processing Factors

Symptoms	Behavioral Control	Cognitive Processing
• Headaches and/or Migraines • Loss of muscle coordination • Blackouts/Fainting • Confusion • Blank staring/Day dreaming • Dizziness • Change in vision • Fatigue • Seizures • Slurred speech • Has trouble finding the "right" word when talking • Noise sensitivity Light sensitivity • Sleepiness • Mood swings	• Coping with change or transitions • Maintaining family and friend relationships • Letting go of one activity to attend to another • Reaction to simple problems • Solving everyday problems • Waiting for his or her turn in a game • Learns from past mistakes or behavior • Thinks before speaking or acting • Listens without interrupting others often • Handles a change in plans • Demonstrates good judgment	• Focusing and maintaining attention • Getting started on activities, tasks, cores, homework and the like, on his or her own • Monitoring own progress on homework, assignments, chores, and the like • Learns new things easily • Remembers lists • Remembers day-to-day events

Results

Development of an Injury Severity Classification Model

An injury-severity classification model was developed as depicted in Figure 1. A number of decisions and assumptions were made to guide its development. The intent of the *Brain Check Survey* (BCS) strongly influenced our approach to creating a model for determining possible severity of brain injury from the reported incidents on the BCS. As mentioned, the BCS was designed to be completed by parents as one of the first steps in the special education evaluation process completed when a child is found to be struggling in school and his/her struggles may be due to past brain injuries. A protocol has been put into place in Colorado for education teams to follow, should the results of a completed BCS indicate problems in behavior and/or symptoms, and/or the child's history indicates enough injury or illness information to warrant further educational and/or psychological evaluation by the school teams. Of course, the ultimate goal of the school's assessment process is to ensure that the child will receive the appropriate services to match his/her needs, and in the case of a TBI, establishing a credible history of past brain injury is an important initial step in the process. We thus attempted to distill as much information from the tool as possible (i.e. specific responses to individual questions in the BCS) that would help establish this history and provide an understanding of the potential severity as described by current TBI severity determinants. Since specific injury severity-related questions in the BCS are limited, and since the intent is to help as many children as possible, we decided to be modestly liberal in our determination of severity, choosing limits and ranges that would include more children and youth than less.

In order for the model to accurately estimate injury severities, the model needed to reflect methods that are currently used within other studies and the medical field. A common

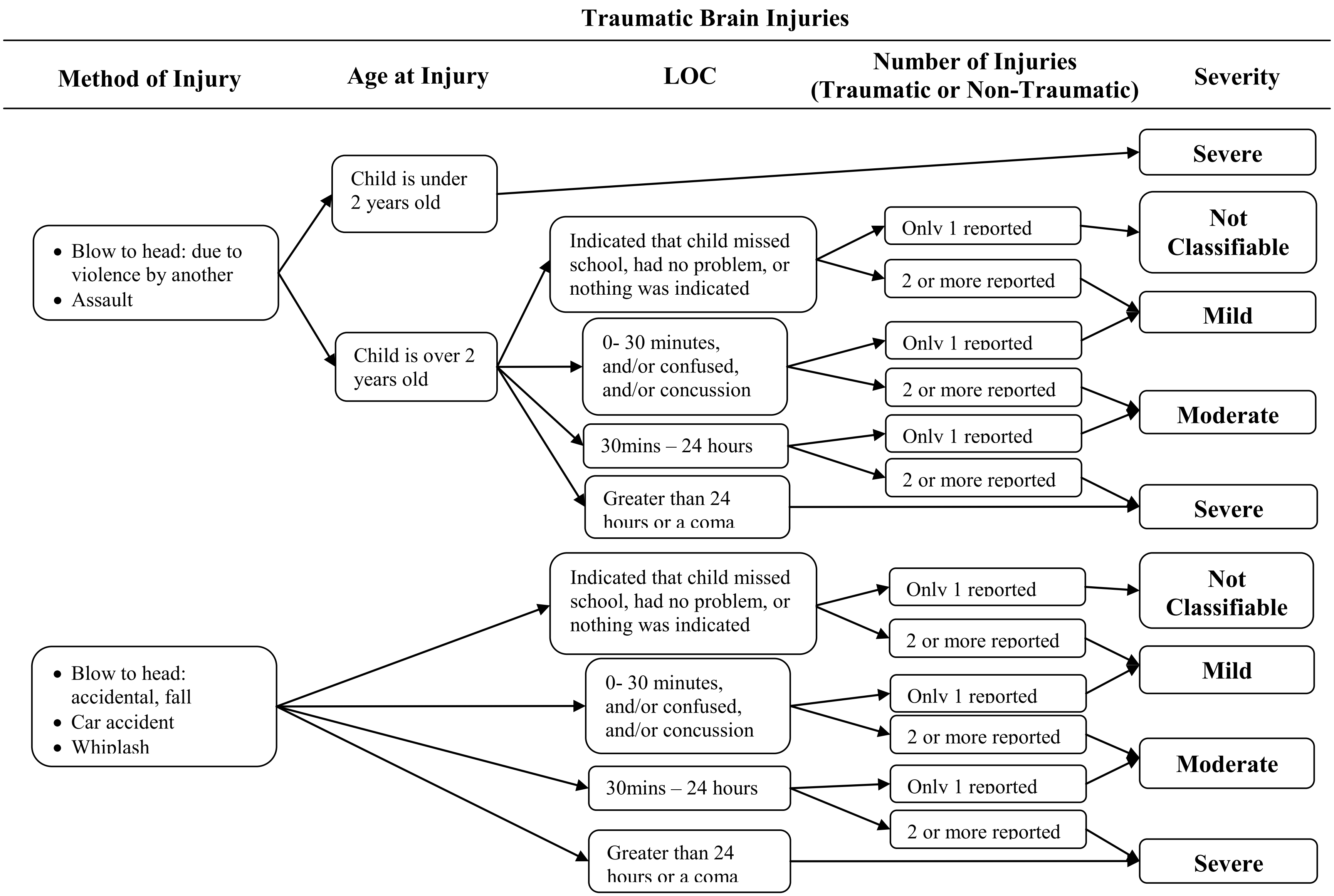

Figure 1. Injury-Severity Classification Model

Non-Traumatic Brain Injuries

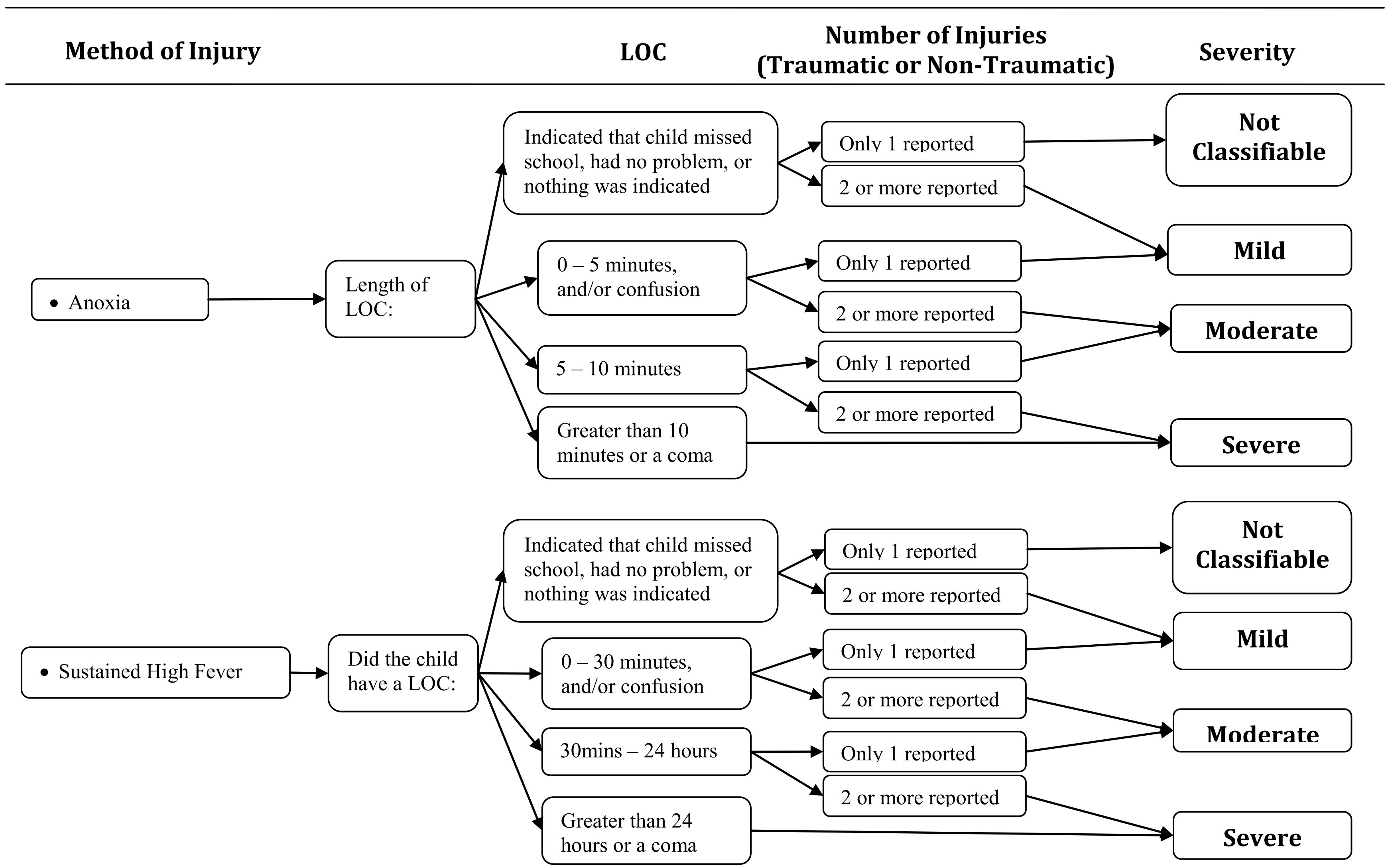

Figure 1. Injury-Severity Classification Model continued

Non-Traumatic Brain Injuries Continued

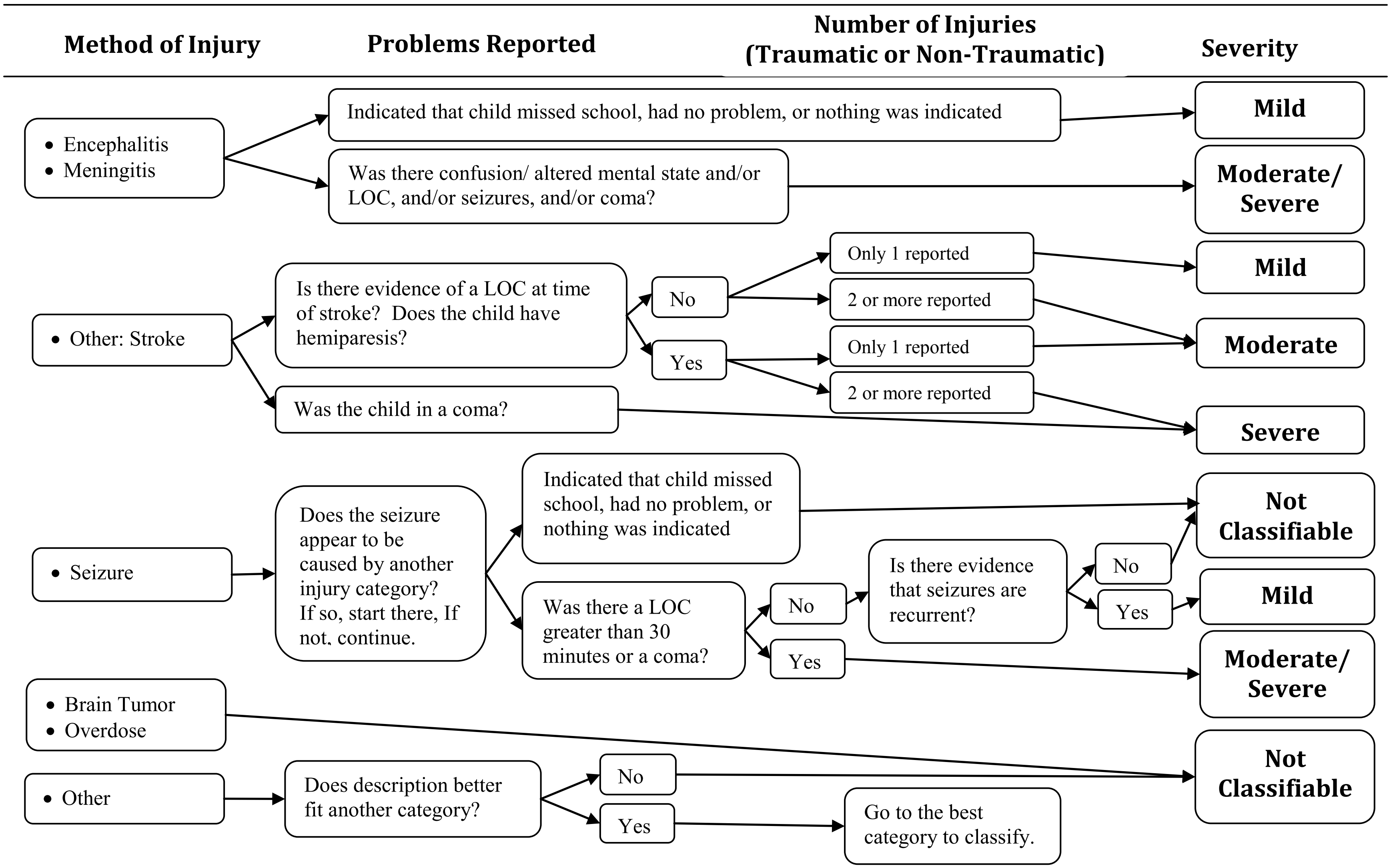

Figure 1. Injury-Severity Classification Model continued

overarching method of determining severity is the Glasgow Coma Scale (GCS) which determines severity from three categories: Eyes Opening, Verbal Response, and Motor Response (Chapman et al., 2010; Cullen, Park, & Bayley, 2008; Ewing-Cobbs et al., 2006; Fay et al., 2009, Garrow & Weinhouse, 1999; Halldorsson et al., 2012; Hooper et al., 2004; Mangeot et al., 2002). The total score of the GCS is used to determine whether an injury is mild, moderate, or severe. Other factors considered by medical professionals in determining severity, may include loss of consciousness (LOC), post traumatic amnesia, brain scans, or presence of skull fractures (Fay et al., 2009; Halldorsson et al., 2012; Mangeot et al., 2002; McKinlay et al., 2008). The BCS, however, does not specifically gather these above factors. Additionally, the BCS includes a variety of types of injuries and illnesses such that one method of classification may not be appropriate for all types. Thus broad categories of brain injury as well as each specific injury category listed on the BCS were researched in order to determine the best criteria for determining severity.

The first approach used to examine the differences between the types of injury and illnesses was to explore how the mechanism of injury is related to severity. Traumatic injuries (those due to an external force) and non-traumatic injuries (those not due to an external force) differ in the damage incurred and often in the cognitive outcomes observed (Babikian & Asarnow, 2009; Ewing-Cobbs et al., 2006). Therefore, the classification model was organized into two primary sections being Traumatic Brain Injuries and Non-Traumatic Brain Injuries. This distinction is also important because the IDEA category of TBI does not cover non-traumatic brain injuries, and children who have sustained non-traumatic brain injuries would need to receive services under a different IDEA category, such as Other Health Impairment (CDE, 2013).

Traumatic brain injuries. Within traumatic brain injuries, examining the differences between focal and diffuse injuries can also be helpful, as they can have different patterns of outcomes. Diffuse injuries can impact multiple areas of the brain and yet not show up in scans. Diffuse injuries also can be especially severe if they impact certain areas of the brain, such as the brainstem (Catroppa, Anderson, Ditchfield, & Coleman, 2008; Cullen, Park, & Bayley, 2008; Duhaime et al., 1992; Smith, Meaney, & Shull, 2003).

Certain mechanisms may be more likely to cause diffuse injury, such as those that are incurred through violence or abuse. Specifically, the literature suggests that the damage to the brain, due to shaking when a child is less than two years old, can be more extensive because the child's head is proportionally larger and heavier and the neck muscles weaker. This allows for more movement and damaging forces on the brain (Salehi-Had, Brandt, Rosas, & Roger, 2006). Furthermore, rotational forces, which often are seen in Shaken Baby Syndrome (SBS), can cause shearing forces which are more damaging to the brain. As King and colleagues explain, "SBS is an extremely serious form of abusive head trauma that occurs when a child is subjected to rapid acceleration, deceleration and rotational forces, with or without impact, resulting in a unique constellation of intracranial, intraocular, and cervical spinal cord injuries" (King, MacKay, & Sirnick, 2003, p. 155). Furthermore, it has been found that a majority of TBIs in children younger than 24 months are due to physical abuse, further substantiating the need to examine mechanism of injury by age, given that these children have poorer outcomes than children who experienced accidental injuries (Ewing-Cobbs et al., 2006). Therefore, if a child's injury was indicated as Shaken Baby Syndrome in comments by parents, or if it was due to child abuse or any other violent impact to the child under the age of two, we considered it to be a severe brain injury.

In cases where violence or abusive injuries were reported in older children and in the categories of non-violent traumatic brain injuries, there was such a wide variation of forces that could be experienced and that could impact the extent of brain injury (for example the impact experienced in a slow-speed car crash versus that experienced in a high speed crash) that other factors need to be considered. As mentioned above, the factor on the BCS that most directly resembles those that are used in the acute determination of severity is LOC. Unfortunately, various guidelines have been proposed for measuring and categorizing length of LOC, which in turn, determines the subsequent severity classification given to the particular child. The Brain Injury Association of America has suggested that a LOC of less than 30 minutes will be mild, less than a few hours moderate, and longer than a few hours will be severe (Brain Injury Association of America [BIAA], 2012). Individual studies may use other guidelines for determining severity by the length of LOC. For example, in some studies a GCS of 12, but with the presence of LOC for more than 15 minutes, will be considered moderate (Fay et al., 2009; Mangeot et al., 2002). Another study classified any LOC less than 20 minutes as mild (McKinlay et al., 2008). We chose to use the criteria of less than 30 minutes for a categorization of mild TBI, as it is used by the BIAA, other governmental departments, like the Department of Veterans Affairs and Department of Defense [VA/DOD], and also is the criterion used by the Colorado Department of Education and the Traumatic Brain Injury Networking Team (TNT) for which the BCS was originally created (The Management of Concussion/mTBI Working Group, 2009; Traumatic Brain Injury Networking Team [TNT], 2013).

Similar differences appear in the literature and guidelines for length of LOC to classify moderate and severe injuries. The BIAA gives vague ranges for LOC (a few minutes to a few hours") (BIAA, 2012), however, we felt it important to give a clear cut-off between these two categories in order to create a model that would be reliable across various practitioners and disciplines. TNT suggests that moderate injuries are those where LOC lasts less than 24 hours which is clearly much greater than a few hours. The studies conducted by Fay et al. (2009), and Mangeot et al. (2002) were examined to give a better understanding of average LOC seen in moderate and severe injuries. These studies were both of children recruited from hospitals who had moderate or severe injuries and reported means and standard deviations for impaired consciousness for moderate and severe injuries. In both the Fay et al. (2009), and the Mangeot et al. (2002) studies, the mean length for moderate injuries was greater than a few hours, with a standard deviation of 14 and 16 hours, respectively. We felt that these studies showed that many moderate injuries may coincide with a LOC that lasts most of a day, and thus felt that choosing the 24 hour criteria used by the TNT would both provide continuity in the process, and was justified by what has been observed in studies of pediatric brain injury. Table 2 is a chart comparing the findings of both studies with the BIAA, TNT, and the criteria we chose for our model.

Table 2

Comparison of criteria for injury severity classification from several sources

	Mild	Moderate Mean(SD)	Severe Mean(SD)
BIAA, 2012	Less than 30 minutes	Less than a few hours	Greater than a few hours
TNT, 2103	Less than 30 minutes	Less than 24 hours	Greater than 24 hours
Fay et al., 2009	Less than 15 minutes	4.32 hours (14.16 hrs)	5.11 days (5.85 days)
Mangeot et al., 2002	Less than 15 minutes	4.80 hours (16.08 hrs)	6.09 days (6.79 days)
Our Criteria	Less than 30 minutes	30 minutes – 24 hours	Greater than 24 hours or a coma or induced coma

Finally, in our model, the last factor included in the severity classification of traumatic injuries is the number of head injuries reported by parents on their child's BCS. Research has shown that multiple injuries to the brain, even if "mild," tend to have a compounding effect, with successive injuries being more severe, requiring longer recovery, and having poorer outcomes and more sequelae (Bohnen, Twijnstra, & Jolles, 1992; Guskiewicz et al., 2003; Halldorsson et al., 2012; Mrazik et al., 2000). This especially has been shown to be the case in sports-related injuries, when a subsequent TBI occurs within several days of a previous TBI (Guskiewicz et al., 2003; Mrazik et al., 2000). In fact, studies on animals have shown that the metabolic changes in the brain during the days following the injury can make the brain more susceptible to any injuries that occur during that period (Guskiewicz et al., 2003). Furthermore, the BCS includes seizures and fever as causes of brain injury categories, yet they also can be counted as possible sequelae of brain injuries that are due to other causes. When seizures or fever do result from another mechanism of brain injury, they often indicate a more severe injury and may display more severe outcomes (deVeber, MacGregor, Curtis, & Mayank, 2000; Greer, Funk, Reaven, Ouzounelli, Uman, 2008; Heindl & Laub, 1996; Klonoff, Clark, Klonoff, 1993). Thus, evidence of multiple injuries on the BCS is considered ultimately suggestive of increasingly severe impact on the brain.

Non-traumatic brain injuries. In our severity classification model, non-traumatic brain injuries (NTBI), or those that were not due to external forces, were classified separately, depending on the etiology of injury. Anoxic injuries, for example, were classified separately from other NTBI causes since previous research has found that anoxic events can have a severe impact on the brain, and potentially more severe of an impact than other types of brain injury (Cullen et al., 2008; Fitzgerald, Aditya, Prior, McNeill, & Pentland, 2010; Heindl & Laub, 1996). While anoxia refers to complete lack of oxygen, damage also can be due to partial lack of oxygen, or hypoxic events, such as may occur in a stroke or certain types of lung diseases (Brainandspinalcord.org, 2012). We presume that parents may not make such distinctions when filling out the BCS, so we have considered anoxic injuries as a broader category that may encompass hypoxic events as well. Severity of hypoxic and anoxic events is generally thought to relate to the length of the LOC: four minutes of anoxia begins to cause cell death and five minutes begins to cause permanent damage to the brain (Brainandspinalcord.org, 2012; Kriel, Krach, Luxenberg, Jones-Seate & Sanchez, 1994). Huang (2008) suggests that for children, arrests of 15 minutes or more produce brain injury, although his sample included hypoxic events rather than full anoxic events. Garrow and Weinhouse (1999) stated that anoxia lasting from greater than eight to ten minutes was an indicator of "unfavorable prognosis" (p. 8). Thus, according to the above data, we chose to consider a LOC reported under the injury category of anoxia (which most likely includes hypoxic events too) of less than five minutes to be a mild injury based on the idea that it is within the first four minutes that cell death begins to occur; LOC lasting five to ten minutes as likely to be moderate since permanent damage begins to occur; and LOC greater than 10 minutes to be severe as lengths greater than 10 minutes are indicators of unfavorable outcomes.

While it is listed as an injury or illness category on the BCS, only fevers above 107.6° F (42° C) are likely to be associated with brain damage (Kaneshiro & Zieve, 2012). Instead, fever is not as much a direct cause of brain injury as it is a symptom of some underlying pathology. Therefore, the severity of the brain damage is best predicted by the underlying cause of the fever. While some common causes of high fever, such as meningitis and encephalitis, are included on the BCS, not all causes are (e.g. pneumonia, tuberculosis, etc). Etiology and exact degrees of fever are not requested on the BCS, thus other factors that are included on the BCS had to be examined to inform the severity classification determination. Again, we believed that the length of a LOC or the presence of a coma, combined with the number of brain-injury related events, would be the best indicators of severity. For example, in infants and young children, altered consciousness, even lethargy, is considered cause to start diagnostic tests for sepsis syndrome/toxicity, a very serious condition with serious implications (Baraff et al., 1993). Furthermore, when fever occurs after brain damage it signifies a risk for poorer outcomes, including increased length of hospital stays and lower scores on functional outcome measures like the Barthel Index (Greer et al., 2008). Thus, if fever has been indicated by a parent in the BCS and appears to have occurred at the same time as another injury marked in the survey, it may be evidence of a brain injury that is more severe than others. If it is clear the fever was related to another injury or illness reported on the BCS by the parent, then that injury or illness should be tracked in the model. If not, though, the fever classification can be followed to determine a likely severity of damage to the brain, due to the reported illness.

Stroke also was classified separately from the other NTBI etiologies. The etiology of stroke and size of lesion are two important factors impacting the severity of the damage (deVeber et al., 2000; Tham, Tay, & Low, 2009), but these clearly were not questions included in the BCS. Stroke scales to assess acute severity have been made for children, as well as for adults, with one such being the Pediatric National Institutes of Health Stroke Scale (PedNIHSS). This scale collects information on a number of clinical presentation factors that are significant to this study: LOC and motor paresis are two of them. LOC is rated by the level of consciousness and ability to respond to or follow commands, rather than the length of the LOC. Paresis is scored by the severity of the affect to the limb (Ichord et al., 2011). While the BCS does not request this depth of information, it seems safe to assume that the presence of LOC or of hemiparesis (which is sometimes indicated in qualitative descriptions written into comment sections of the BCS) would indicate a more severe stroke. LOC has been verified by recent studies as a potential prognostic factor related to poorer outcomes (Goldenberg, Bernard, Fullerton, Gordon, deVeber, 2009; Lyle, Bernard, & Goldenberg, 2011). The presence of a coma would indicate a severe brain insult, just as it would be indicative of such by increasing the score and the resulting implication for severity on a measure like PedNIHSS (Ichord et al., 2011).

Additionally, it seems that when stroke occurs along with another neurological disorder, the impact to the brain is more severe. In a prospective study of children who sustained a stroke, deVeber and colleagues (2000) found that presence of associated neurologic disorders occurring at the time of stroke predicted poor outcomes. These associated disorders included meningitis, hypoxic-ischemic injury, status epilepticus, and head trauma with a loss of consciousness. Hartel, Schilling, Sperner, and Thyen (2004) in their review of the literature, also found that the presence of associated seizure disorders was found to be a risk factor for poor cognitive outcomes after stroke. A meta-analysis (Greer et al., 2008), found that the presence of a fever after stroke was associated with worse outcomes. Our severity classification model therefore addresses these concerns by taking into account the number of injuries indicated on the BCS.

As mentioned above, both meningitis and encephalitis are underlying causes of high fevers and may lead to brain damage. Meningitis can have many different causes with presenting symptoms including fever, mental status changes, nausea, sensitivity to light, headache, agitation, rapid breathing, and unusual posture (Dugdale, Vyas, & Zieve, 2012). Meningitis that is due to a bacterial infection can be especially severe, and if not treated immediately, can lead to permanent brain damage (Dubos et al., 2008; Dugdale et al., 2012). Thus having medical personnel determine the cause of meningitis as quickly as possible is important, and several criteria are used to do so, including history of seizures with the illness, blood neutrophil count, CSF Gram stain, CSF protein, and CSF neutrophil count (Dubos et al., 2008). Additionally, mental status tends to deteriorate with time. Unconsciousness, delirium and seizures can occur in as soon as 15 hours in infants and 24 hours in older children (Pace & Pollard, 2012). In some cases, the Glasgow Coma Scale (GCS) also is used to classify severity of illness in children and adults with meningitis. According to a study conducted by Merkelbach, Röhon, König, and Müller (1999), the initial GCS score was found to be significantly associated with the clinical outcome. In another study by Bohr and colleagues in 1985, altered consciousness with meningitis was related to more severe outcomes and possible mortality. Furthermore, agitation and confusion were associated with worse outcomes to such a degree that they concluded that "agitation and confusion thus appear to carry as serious a prognosis as increasing lethargy, drowsiness, and coma" (Bohr et al., 1985, p. 156). Thus confusion, altered mental state, LOC, seizures, or a coma all may indicate that moderate to severe brain damage has occurred in persons who survived having meningitis.

Encephalitis also can have multiple causes, many of which are due to viral infections. Diagnosis of encephalitis is made based upon multiple factors, including abnormal electroencephalography (EEG) findings, abnormal neuro-imaging findings, positive focal neurologic findings, seizure, encephalopathy, elevated temperature, signs of inflammation, and elevated infectious parameters (Fowler, Stödberg, Eriksson, & Wickström, 2010). Certain clinical presentations are considered emergency situations, including altered consciousness (which includes coma), seizures, headaches, and/or sudden changes in mental functioning

(Kaneshiro & Zieve, 2012). Therefore, as in meningitis, if parents note on the BCS that their child had confusion, altered mental state, LOC, seizures, or coma related to the child having encephalitis, it lends evidence that, quite probably, a moderate to severe injury occurred to the child's brain, which is then reflected in the classification model.

Seizures are another injury category listed on the BCS. Seizures do not necessarily cause brain damage in and of themselves, but in some cases may be more likely to than others. For example, a seizure may be more likely to cause brain damage if the brain already has experienced an insult or may be a symptom an underlying pathology such as an infection, traumatic injury, or other congenital factor (Lado, Laureta, & Moshé, 2002). Thus, our severity classification model inquires if the seizure was due to another injury category or whether the seizure was an independent incident. When the seizure appears to be an independent occurrence, it can be helpful to distinguish the type of seizure, as some types of seizures are more likely to cause brain damage. One such case being status epilepticus, which is defined as a seizure that lasts for 30 minutes or when a period of LOC of 30 minutes occurs with seizures (Holmes, 1991). Studies have shown that status epilepticus does have a higher incidence of causing long-term damage to the brain. (Holmes, 1991; Lado, Laureta, & Moshé, 2002; Trinka, Höfler & Zerbs, 2012). There also is some evidence that over time, recurrent seizures, as seen in epilepsy, may lead to cognitive deficits and that some of the medications taken for seizures may also contribute to brain damage (Holmes, 1991). Therefore, the model determines if there was a prolonged period of LOC or coma, which may indicate a more severe type of seizure, like status epilepticus. If not, the severity classification model inquires whether the seizures are ongoing, which may indicate that damage may be occurring over time and contributing to brain injury.

Brain tumors also are a source of brain injury in young children. The initial severity and effects on functioning are related to the size and location of the tumor, which often, then, is later compounded with the effects of surgery, chemotherapy, and radiation therapy (Brière, Scott, McNall-Knapp, & Adams, 2008). None of the above factors are prompts on the BCS, and the information needed about them in order to make a justifiable severity classification would not likely be reported. Therefore, the severity of a student's brain tumor is not classifiable in our methods. If a child is referred for special services and brain tumor is reported by the parents on the BCS, then teachers and parents would need to rely more on other methods of determining need for services, and the justification necessary for an IEP.

Overdose is the final category of injury or illness on the BCS. There are many different substances that cause overdose, such as alcohol, various prescription drugs, and even chemicals used around the home. The type and amount of substance that caused the overdose are two important factors impacting the extent of brain damage that may have been incurred. These two factors, are not, however, collected on the BCS. While case studies have demonstrated that overdose can lead to neurologic damage and sequelae, such as hypoxia, seizures, stroke, and coma (Heard & Schaeffer, 2011; Richter et al., 1973; Rogers, Denk, & Wax, 2004; Thundiyil, Rowley, Papa, Olson, & Kearney, 2011) there were no large scale studies found examining the factors that are used to determine the severity of an overdose in children. Therefore, it was felt that at this time, the severity of an overdose would not be able to be accurately classified with the information given on the BCS in relation to published literature.

A final note about the model and intent of the BCS is that it is meant to categorize only those incidents of injury or illness that occur after birth. There are certain events that can occur in utero, such as a stroke or even an overdose if the mother abuses substances during her pregnancy. These types of incidences were occasionally reported on the BCS; however, the CDE specifically states that the brain injury must occur after birth to technically classify as an acquired brain injury (CDE, 2013). Thus, the model is not intended to classify these events, and if such an event is reported on the BCS, the educator or specialist would be advised to inquire further but consider a different educational identification for the student other than TBI.

Inter-rater Reliability

Comparison of the two researchers' decisions in the classification process yielded 95% agreement, which was found to be significant (k=0.867, p<0.001) for the TBI group. Similarly a significant result (k=0.800, p<0.001) with 92.5% agreement was reached for the TypHx group. Both scores indicated high inter-rater reliability of the classification model, which encourages the BCS developers and researchers in their efforts to create a tool that can be used and interpreted by a variety of special education evaluation team members in any school district.

Exploration of the Model's Utility

All participants in the TBI group were classified according to the injury-severity classification scheme. The classification resulted in the following student severity ratings: 23 Severe, seven Moderate, five Moderate/Severe, eight Mild, and eight could not accurately be classified with the information reported on the BCS. For the purposes of statistical analysis, the Moderate/Severe group was included in the Moderate group as many of these were due to non-traumatic brain injuries such as encephalitis, meningitis, and seizures that we believe may more likely have resulted in moderate injuries rather than severe injuries based on the information reported by parents. The twenty randomly selected TypHx participants used to study inter-rater reliability also were included in statistical analysis. Of these twenty, the severity ratings were as follows: one Severe, 10 Mild, and nine could not accurately be classified. Additional TypHx participants, who were previously classified according to the model, were included in order to increase group numbers for statistical analysis. The total severity ratings for the TypHx group were as follows: one Severe, 17 as Moderate, 20 as Mild, and nine that could not be classified. The one Severe TypHx case was included in the TypHx group classified as Moderate, due to low group numbers. It was felt that this was justified as the goal is not so much to label students with a severity, but to be able to identify students who have experienced injuries or illnesses that were significant enough to impact their school functioning. The participants who could not be classified were not included in statistical analyses. An ANOVA was performed on the resulting five injury groups (TBI Severe, TBI Moderate, TBI Mild, TypHxMod/Sev, and TypHxMild), using the summed scores of the three dependent variables described (Symptoms, Behavioral Control, and Cognitive Processing).

The mean total scores of the resulting groups for each of the three variables were explored, and boxplots were created as depicted in Figure 2, 3, and 4. The ANOVA for each dependent variable was found to be significant (Symptoms Total Score F=5.339, p<0.001; Cognitive Processing Total Score F=27.531, p<0.001, Behavioral Control Total Score F=18.233,

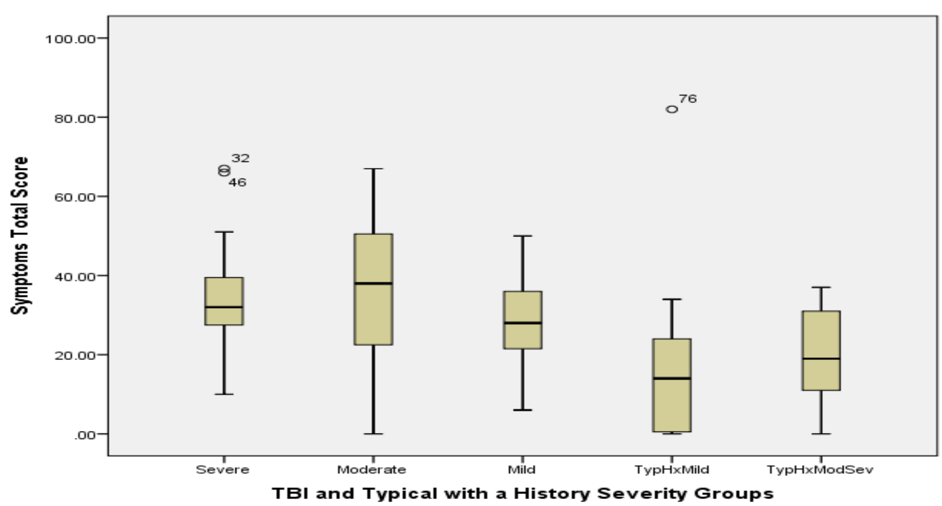

Figure 2. TBI and Typical with a History Severity Groups Symptom Total Scores

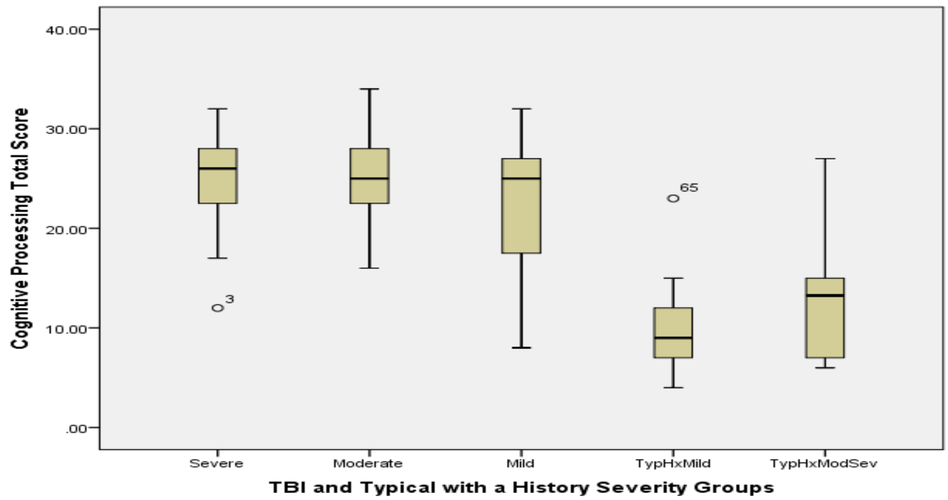

Figure 3. TBI and Typical with a History Severity Groups Cognitive Processing Total Scores

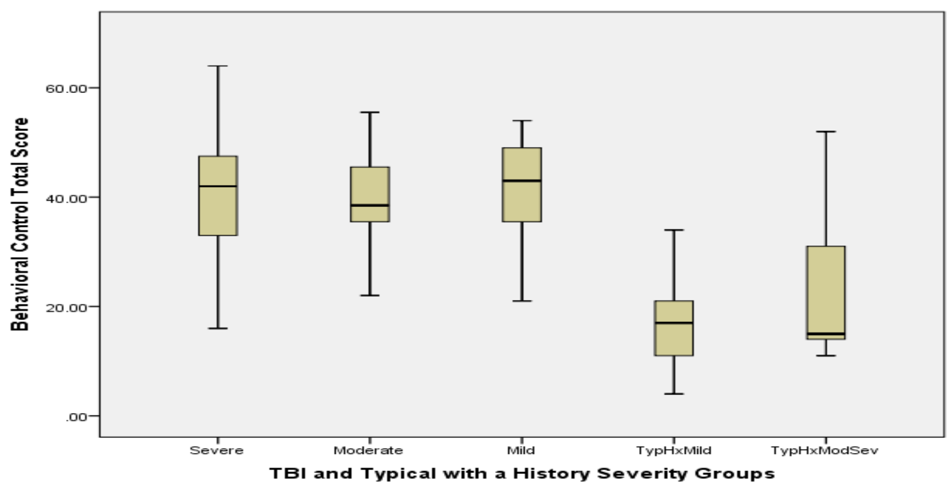

Figure 4. TBI and Typical with a History Severity Groups Behavioral Control Total Scores

p<0.001), indicating that at least one significant difference existed between the severity groups for each dependent variable. Post hoc analysis (Tukey) revealed that the three main TBI severity groups (Severe, Moderate, and Mild) were not significantly different from one another on any of the dependent variables. The two TypHx groups also were not found to be significantly different from one another on any of the dependent variables. (See Table 3.) The TypHxMod/Sev and TypHxMild groups, however, were significantly different from the three TBI severity groups for Cognitive Processing and Behavior Control Subtests. The two TypHx groups also were significantly different from the Severe and Moderate TBI groups on Symptoms Score but were not significantly different from the Mild TBI group on Symptoms Score.

Table 3

Group Comparisons and Univariate Tests

	Symptoms		**Cognitive Processing**		**Behavioral Control**	
	Mean(SD)	Sig.	Mean (SD)	Sig.	Mean (SD)	Sig.
Severe	33.9 (14.6)	.985	25.1 (5.0)	1.000	39.6 (12.1)	1.000
Moderate	36.9 (18.8)		25.1 (5.6)		39.5 (9.1)	
Severe	33.9 (14.6)	.913	25.1 (5.0)	.765	39.6 (12.1)	.996
Mild	28.4 (13.1)		22.3 (7.7)		41.3 (10.8)	
Severe	33.9 (14.6)	.045	25.1 (5.0)	.000*	39.6 (12.1)	.000*
TypHxMod/Sev	19.7 (12.4)		13.6 (7.0)		22.7 (13.6)	
Severe	33.9 (14.6)	.005*	25.1 (5.0)	.000*	39.6 (12.1)	.000*
TypHxMild	16.5 (18.9)		9.9 (4.2)		17.0 (6.6)	
Moderate	36.9 (18.8)	.768	25.1 (5.6)	.892	39.5 (9.1)	.997
Mild	28.4 (13.1)		22.3 (7.7)		41.3 (10.8)	
Moderate	36.9 (18.8)	.039	25.1 (5.6)	.000*	39.5 (9.1)	.001*
TypHxMod/Sev	19.7 (12.4)		13.6 (7.0)		22.7 (13.6)	
Moderate	36.9 (18.8)	.007*	25.1 (5.6)	.000*	39.5 (9.1)	.000*
TypHxMild	16.5 (18.9)		9.9 (4.2)		17.0 (6.6)	
Mild	28.4 (13.1)	.704	22.3 (7.7)	.005*	41.3 (10.8)	.001*
TypHxMod/Sev	19.7 (12.4)		13.6 (7.0)		22.7 (13.6)	
Mild	28.4 (13.1)	.392	22.3 (7.7)	.000*	41.3 (10.8)	.000*
TypHxMild	16.5 (18.9)		9.9 (4.2)		17.0 (6.6)	
TypHxMod/Sev	19.7 (12.4)	.972	13.6 (7.0)	.270	22.7 (13.6)	.493
TypHxMild	16.5 (18.9)		9.9 (4.2)		17.0 (6.6)	

Note: * indicates significance at $p < 0.05$

Discussion

The Injury-Severity Classification Model (ISCM) appears to be a reliable way to determine the possible severity of past injuries recorded by parents on the BCS. It identifies many of the injuries in the existing TBI group as severe; this may be expected since these children already have received an IEP based on needing special education support after having sustained a brain injury. The ISCM also was able to distinguish participants in the group identified as typical with a history of illness or injury that may have had less severe injuries, as it identified injury severities for participants who currently do not have an IEP but whose parents did report a history of injury or illness. As expected, the majority of these cases were classified as mild injuries; however, a small proportion could be classified as having sustained a potentially moderate or severe head injury. These results suggest that the model does not grossly misclassify severities of past brain injuries and is sensitive enough to distinguish levels of severity using the information provided on the BCS.

The data analyses did not show significant differences among the severity levels in the TBI group on any of the BCS subtest scores (Symptoms, Behavioral Control or Cognitive Processing). There also were no differences found between the severity ratings of TypHx groups. The TypHx groups and the TBI groups showed a statistically significant difference in Behavioral Control and Cognitive Processing subtests. The TypHx groups, however, were not found to be significantly different from the Mild TBI group on the Symptoms total score. These results are not overly surprising as it might be expected that an already identified TBI group likely would have more severe injuries, symptoms, behaviors, and cognitive difficulties than a group of typical students. One interesting result is that TypHx students may actually present with symptoms that are similar to those reported in a TBI group that the model classified as mild.

This is promising in that it shows there may be a rough continuum of symptoms among the severity groups. In the future use of the BCS in schools, the students presenting with symptoms similar to those seen in this mild TBI group, may be especially appropriate for closer examination or referral to determine if they may indeed have sustained an TBI that could be contributing to challenges in school, and if they therefore may benefit from having an IEP or 504 plan to support their in-school functioning.

There are many reasons why clearer differentiations in symptoms, behaviors, and cognitive items among the severity levels in the TBI and TypHx groups did not occur. Factors such as age at injury, time since injury, pre-injury functioning, and family functioning, all mediate the outcomes observed after a brain injury (Anderson et al., 2009; Catroppa et al., 2007; Kriel et al., 1994; Levac et al., 2008). For example, children who sustain an early mild injury may not present with behavioral or cognitive challenges until their early teen years, when executive functioning really begins to mature and when higher level skills are expected from them (Schutz, Rivers, McNamara, Schutz, & Lobato, 2010; Tonks et al., 2011). Furthermore, times of developmental vulnerability have been proposed that may mediate outcomes, such that a child sustaining a brain injury of a certain severity during a vulnerable period may present with poorer outcomes than a child sustaining a brain injury of the same or greater severity during a more stable or resilient age (Anderson et al., 2009). Since the BCS was administered to children of a variety of ages in this study, many may have scored differently in the three subtests of the BCS based on age and latency in developing problematic behaviors and cognitive functioning as well as the initial severity of their injury. Finally, factors such as family functioning also can mediate outcomes, where children in better functioning families present with better outcomes than those children who may have faced family and social challenges like foster care, poverty, or poor family functioning (Catroppa et al., 2007; Levac et al., 2008). These variables were not included in the analysis at this time, but may be mediating factors, along with the severity of injury, obscuring differences observed in symptoms, behavioral control, and cognitive processing among the severity groups.

Future research might include studies involving larger samples of various brain injury severity categories. The limited number of participants with TBI (especially those which the model classified as having sustained moderate and mild injuries) may have been a poor representation of these groups in the school system setting. Also, since age at time of injury, age at completion of the BCS, and family functioning may be factors in later behavioral and cognitive functioning of children with brain injury, future studies should incorporate study methods that can take these factors into account, or employ inclusion/exclusion criteria or methods to control for the effects of these variables

Additionally, future research efforts may explore possible ways to revise the “Injuries and Illnesses” component of the BCS as well as the Injury Severity Classification Model in order to allow for greater sensitivity and accuracy in determining injury severity. Ultimately, it will be important to ensure that educators have clear guidelines for interpreting the information reported on the BCS and for using it to make decisions about whether to refer a child for more complete evaluation and possible identification of TBI.

Limitations

An inherent limitation of the Injury-Severity Classification Model (ISCM) is the challenge posed by using an educational tool to create categories that are otherwise determined by medical means. As the literature was reviewed for criteria for the model to use to determine injury severity levels, many of the criteria found were not included or requested in the BCS, such as EEG findings, bacterial cultures, or most commonly the Glasgow Coma Scale score. Thus, the ISCM had to rely on a limited amount of information. Furthermore, this information was a parental report, often of events that occurred years previously, which certainly could introduce error. A good number of the children included in the study were living with adoptive or foster families who were not present when the injury occurred and therefore, important information, such as a length of loss of consciousness, was unknown. Even when known, loss of consciousness had its limits as a severity criterion, as well. For example, LOC in infants may not always occur with brain injury, and instead, other behaviors may be seen (Halldorsson et al., 2012). Thus, our scheme of categorization may be less valid for very young children.

Furthermore, there also is growing recognition within this field of research that severity of brain injury determined acutely may not correlate well with the long term severity of impact (CDE, 2013). There are many reasons why this may be so, but in any case, determinations of injury severity do not fully describe or predict a child's actual later functioning. Therefore, classification of severity of injury based off of the model is in no way meant to be diagnostic, but is instead only meant to provide more information to teachers and school staff about the child, and why he/she may be experiencing difficulties in school. As school staff use the BCS in a TBI identification process, they would be highly encouraged to use it as a method for opening conversation with families, with the goal of providing the best and most appropriate services to support their child or adolescent's school success.

Conclusion

The "Injuries and Illnesses" component of the *Brain Check Survey* yields enough information for estimates of severity of brain injury to be made based on the Injury-Severity Classification Model developed in this study. The ISCM has excellent inter-rater reliability and is able to distinguish levels of severity of reported injuries and illnesses both among a group of students currently receiving school-based services for a known TBI and among students who are considered typically developing but whose parent(s) report past brain injuries. The model thus may be helpful in interpreting the "Injuries and Illnesses" portion of the BCS and in contributing to the decision making process of educational teams as they seek to identify students who may need additional school support due to challenges related to brain injuries.

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Appendix

Brain Check Survey

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Brain Check Survey

Parent/Guardian Version

Student Information

Today's Date: ___/___/___ Child's Age: _______
Child's Date of Birth: ___/___/___ Child's Gender: ☐ Male ☐ Female

Child's race: (circle one or more)	1: American Indian/Alaska Native 2: Asian 3: Native Hawaiian or Other Pacific Islander	4: Black or African American 5: White 6: More than one race Please describe:_______________
Child's ethnicity: (circle one)	1: Hispanic or Latino 2: Not Hispanic or Latino	3: Unknown or Not Reported

Injuries or Illnesses

Injury or Illness	Age	Outcomes
Please check all that apply		
☐ **Blow to Head** (from sports, playing, biking, falling, getting hit by an object, etc.)	At what age?____	Check all that apply: ☐ Concussion ☐ Loss of consciousness, *for how long?______ ☐ Coma, *for how long? ________ ☐ Confusion or altered mental state ☐ Missed school ☐ Resulted in no problem

Injury or Illness	Age	Outcomes
☐ **Whiplash**	At what age?____	Check all that apply: ☐ Concussion ☐ Loss of consciousness, *for how long?______ ☐ Coma, *for how long? ________ ☐ Confusion or altered mental state ☐ Missed school ☐ Resulted in no problem
☐ **Car accident** (resulting in any degree of injury or lack of injury)	At what age?____	Check all that apply: ☐ Concussion ☐ Loss of consciousness, *for how long?______ ☐ Coma, *for how long? ________ ☐ Confusion or altered mental state ☐ Missed school ☐ Resulted in no problem
☐ **Assault/Violence (child abuse, fights, firearm injury)**	At what age?____	Check all that apply: ☐ Concussion ☐ Loss of consciousness, *for how long?________ ☐ Coma, *for how long? ________ ☐ Confusion or altered mental state ☐ Missed school ☐ Resulted in no problem
☐ **Sustained High Fever**	At what age?____	Check all that apply: ☐ Loss of consciousness, *for how long?________ ☐ Coma, *for how long? ________ ☐ Confusion or altered mental state ☐ Missed school ☐ Resulted in no problem
☐ **Brain Tumor**	At what age?____	Check all that apply: ☐ Loss of consciousness, *for how long?________ ☐ Coma, *for how long? ________ ☐ Confusion or altered mental state ☐ Missed school ☐ Resulted in no problem

Injury or Illness	Age	Outcomes
☐ **Anoxia** (definition: lack of oxygen; caused by such events as a near-drowning experience or suffocating experience)	At what age?____	Check all that apply: ☐ Loss of consciousness, *for how long?________ ☐ Coma, *for how long? ________ ☐ Confusion or altered mental state ☐ Missed school ☐ Resulted in no problem
☐ **Meningitis**	At what age?____	Check all that apply: ☐ Loss of consciousness, *for how long?________ ☐ Coma, *for how long? ________ ☐ Confusion or altered mental state ☐ Missed school ☐ Resulted in no problem
☐ **Encephalitis**	At what age?____	Check all that apply: ☐Loss of consciousness, *for how long?________ ☐Coma, *for how long? ________ ☐Confusion or altered mental state ☐Missed school ☐ Resulted in no problem
☐ **Seizures** (example: epilepsy)	At what age?____	Check all that apply: ☐ Loss of consciousness, *for how long?________ ☐ Coma, *for how long? ________ ☐ Confusion or altered mental state ☐ Missed school ☐ Resulted in no problem
☐ **Overdose of** drugs or alcohol, or inappropriate use of prescription drugs or over- the-counter medication?	At what age?____	Check all that apply: ☐ Loss of consciousness, *for how long?________ ☐ Coma, *for how long? ________ ☐ Confusion or altered mental state ☐ Missed school ☐ Resulted in no problem
☐ **Other:** __________ _________________	At what age?____	Check all that apply: ☐ Concussion, *for how long? ________ ☐ Loss of consciousness, *for how long?________ ☐ Coma, *for how long? ________ ☐ Confusion or altered mental state ☐ Missed school ☐ Resulted in no problem

Injury or Illness	Age	Outcomes
☐ **Other:** _________ _______________	At what age?____	Check all that apply: ☐ Concussion, *for how long? ________ ☐ Loss of consciousness, *for how long?________ ☐ Coma, *for how long? ________ ☐ Confusion or altered mental state ☐ Missed school ☐ Resulted in no problem

Has your child ever been to the emergency department? ☐ *Yes* ☐ *No*
If YES, at what age?________ Please explain:

____

____

____

____

Behaviors that can affect learning

Please tell us about your child's learning styles and behaviors

Learning Style or Behavior	Not Applicable? (check)	Circle the number on the scale which best describes your child: No Problem ⇔ Extreme Problem					
	☐ N/A	**1**	**2**	**3**	**4**	**5**	**6**
Focusing and maintaining attention	☐ N/A	1	2	3	4	5	6
Getting started on activities, tasks, chores, homework and the like, on his or her own	☐ N/A	1	2	3	4	5	6
Being understood (speech is easy to understand, speaks clearly)	☐ N/A	1	2	3	4	5	6
Understanding others	☐ N/A	1	2	3	4	5	6
Coping with change or transitions	☐ N/A	1	2	3	4	5	6
Maintaining family and friend relationships	☐ N/A	1	2	3	4	5	6
Letting go of one activity to attend to another	☐ N/A	1	2	3	4	5	6
Reaction to simple problems	☐ N/A	1	2	3	4	5	6
Monitoring own progress on homework, assignments, chores, and the like	☐ N/A	1	2	3	4	5	6

Learning Style or Behavior	Not Applicable? (check)	Circle the number on the scale which best describes your child: No Problem ⟺ Extreme Problem
Solving everyday problems (example: thinking of different options when something is not working for him/her.)	☐ N/A	1 2 3 4 5 6
Waiting for his or her turn in a game	☐ N/A	1 2 3 4 5 6
Learns from past mistakes or behavior	☐ N/A	1 2 3 4 5 6
Thinks before speaking or acting	☐ N/A	1 2 3 4 5 6
Listens without interrupting others often	☐ N/A	1 2 3 4 5 6
Handles a change in plans	☐ N/A	1 2 3 4 5 6
Demonstrates good judgment	☐ N/A	1 2 3 4 5 6
Learns new things easily	☐ N/A	1 2 3 4 5 6
Remembers lists	☐ N/A	1 2 3 4 5 6
Remembers day-to-day events	☐ N/A	1 2 3 4 5 6

Symptoms

If your child has experienced any of the following symptoms, rank the severity of those symptoms.
Please check all that apply:

Symptom	Not Applicable? (check)	Circle the number on the scale which best describes your child: No Problem ⟺ Extreme Problem
	☐ N/A	**1 2 3 4 5 6**
Headaches and/or Migraines (sudden, not responsive to medications, can last for more than a day)	☐ N/A	1 2 3 4 5 6
Loss of muscle coordination (can look like awkward movements, problems with balance, slowed reactions, uncoordinated running and catching)	☐ N/A	1 2 3 4 5 6
Blackouts/ Fainting	☐ N/A	1 2 3 4 5 6

Symptom	Not Applicable? (check)	Circle the number on the scale which best describes your child: No Problem ⟺ Extreme Problem
Confusion	☐ N/A	1 2 3 4 5 6
Blank staring/Day dreaming	☐ N/A	1 2 3 4 5 6
Dizziness	☐ N/A	1 2 3 4 5 6
Change in vision (blurred vision, double vision, depth perception)	☐ N/A	1 2 3 4 5 6
Fatigue (tires easily, is often tired)	☐ N/A	1 2 3 4 5 6
Seizures	☐ N/A	1 2 3 4 5 6
Slurred speech	☐ N/A	1 2 3 4 5 6
Has trouble finding the "right" word when talking	☐ N/A	1 2 3 4 5 6
Noise sensitivity (can be easily upset by loud noises or specific sounds like a ticking clock.)	☐ N/A	1 2 3 4 5 6
Light sensitivity (can be easily upset by bright or strobe lights)	☐ N/A	1 2 3 4 5 6
Sleepiness (has trouble staying awake during the day)	☐ N/A	1 2 3 4 5 6
Mood swings (unusual and/or quick changes between sadness, happiness, depression, anxiety, anger and the like; irritability)	☐ N/A	1 2 3 4 5 6

Educational Services

*Is your child having difficulties with school performance? Please describe:*______________________

____

____

*What does your child do best at in school? Please describe:*___________________________________

____

____

Is your child currently receiving any of the following services?

Check all that apply (If "yes", please check if they are provided through school and/or being provided privately).

Service	*Child's Status (please check)*

Occupational therapy	☐ **No**	☐ **Yes** If Yes, please check whether these services are delivered by: ☐ *school-supported specialists* (the school pays for the specialist); and/or ☐ *by private specialists* (you and/or your insurance pays)
Physical therapy	☐ **No**	☐ **Yes** If Yes, please check whether these services are delivered by: ☐ *school-supported specialists* (the school pays for the specialist); and/or ☐ *by private specialists* (you and/or your insurance pays)
Speech-Language therapy	☐ **No**	☐ **Yes** If Yes, please check whether these services are delivered by: ☐ *school-supported specialists* (the school pays for the specialist); and/or ☐ *by private specialists* (you and/or your insurance pays)
Other: ________	☐ **No**	☐ **Yes** If Yes, please check whether these services are delivered by: ☐ *school-supported specialists* (the school pays for the specialist); and/or ☐ *by private specialists* (you and/or your insurance pays)

Has your child ever been evaluated for special education services? ☐ YES ☐ NO

If Yes, at what age was your child first evaluated? ____________

Does your child have a 504 plan? ☐ YES ☐ NO

If Yes, are the accommodations helping your child's school performance? ☐ YES ☐ NO

Does your child have an IEP, Individualized Education Plan?

☐ **No**

☐ **Yes** → if YES, please answer 1 & 2 immediately below:

1. Is the IEP helping your child's school performance? ☐ YES ☐ NO
2. Please check all categories listed on the IEP:
   - ☐ Autism
   - ☐ Hearing Disability
   - ☐ Multiple Disabilities
   - ☐ Physical Disability - Conditions such as, but not limited to, attention deficit disorder, attention deficit hyperactivity disorder, and cerebral palsy may qualify as a physical disability
   - ☐ Pre-School Child with a Disability
   - ☐ Significant Identifiable Emotional Disability (SIED)
   - ☐ Specific Learning Disability (SLD)
   - ☐ Speech-Language Impairment
   - ☐ Significant Limited Intellectual Capacity (SLIC)
   - ☐ Traumatic Brain Injury (TBI)
   - ☐ Vision Disability
   - ☐ Other___________________

Family Information

*Please answer the following questions about **YOURSELF***

Are you the student's (circle all that apply):

☐ Mother ☐ Father ☐ Foster Parent ☐ Other (ex: stepmother) please describe:_____________

Your Age: _______ **Date of Birth**: __/__/__

Your race: (circle one or more)	1: American Indian/Alaska Native 2: Asian 3: Native Hawaiian or Other Pacific Islander	4: Black or African American 5: White 6: More than one race Please describe:______________
Your ethnicity: (circle one)	1: Hispanic or Latino 2: Not Hispanic or Latino	3: Unknown or Choose not to Report

What is your highest level of education? (Check one.) This question is optional.

☐ Some high school ☐ High school graduate ☐ Some college
☐ College graduate (Associate's Degree) ☐ College graduate (Bachelor's Degree) ☐ Some graduate training
☐ Doctorate or professional degree (lawyer, PhD., M.D., etc.)
☐ Master's Degree

Family Gross Income (Before taxes-- check one.) This question is optional.
Note: If parents are divorced and child lives in both families, then record the income of both households separately.

1. less than $5,000	8. $35,001 to $40,000	15. $90,001 to $100,000
2. $5,000 to $10,000	9. $40,001 to $45,000	16. $100,001 to $150,000
3. $10,001 to $15,000	10. $45,001 to $50,000	17. $150,001 to $200,000
4. $15,001 to $20,000	11. $50,001 to $60,000	18. $200,001 to $250,000
5. $20,001 to $25,000	12. $60,001 to $70,000	19. $250,001 to $300,000
6. $25,001 to $30,000	13. $70,001 to $80,000	20. more than $300,000
7. $30,001 to $35,000	14. $80,001 to $90,000	

Thank you very much for your time!