Integration of Neuropsychology in Educational Planning Following Traumatic Brain Injury

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**ABSTRACT:** Traumatic brain injuries (TBIs) have the potential to significantly disrupt a student’s cognitive, academic, social, emotional, behavioral, and physical functioning. It is important for educators to appreciate the array of difficulties students with TBI may experience in order to appropriately assess needs and create an educational plan that targets the needs. The purpose of this article is to provide an overview of the neuropsychological aspects of TBI and the implications these have on the role of educators. The author reviews the physical aspects of TBI, and summarizes the neuropsychological outcomes, with particular attention given to injury variables that impact assessment decisions. The author describes common challenges with the assessment of educational needs with emphasis placed on developing a hypothesis testing approach to information gathering and formal assessment.

Students who have sustained a traumatic brain injury (TBI) represent a diverse population that exhibit the full spectrum of educational needs. Brain injuries clearly carry with them the potential to significantly disrupt a student’s learning, and injuries affect aspects of social, emotional, behavioral, and physical functioning as well. Because of the diverse nature of TBI in children and adolescents, and because disciplines such as education and neuropsychology frequently do not interact closely, these students pose a unique and sometimes daunting challenge in the school setting. In this article, I provide an overview of the neuropsychological aspects of TBI and the implications these have for the role of educators. I provide an overview of the physical aspects of TBI and discuss variables, such as severity of injury and age at injury. I summarize the effects of TBI on various neuropsychological domains and address challenges associated with assessment of educational needs. Finally, I provide recommendations regarding assessment strategies as well as using information gathered during assessment to guide intervention decision making.

**Physiological Aspects of TBI**
TBI sets in motion a cascade of pathophysiologic processes that continues for some time after the point of initial impact. The process of brain damage and the subsequent physiologic changes are a dynamic process that continues for some time following the actual traumatic injury (Bigler, 1997). It is important for educators working with students with TBI to have at least a cursory understanding of the physiological aspects of brain injury in order to better understand, predict, and plan for the student’s educational needs.

There are a number of ways to classify the physical sequelae of TBI. Injuries might be characterized as open/penetrating or closed, and resulting damage can be referred to as focal or diffuse. Focal effects of brain injuries include the primary point of contusion, tearing of surface vasculature, intracranial hemorrhage, and focal compression/laceration of brain tissue. Brain trauma can also result in diffuse physical damage that includes stretching and shearing of nerve fibers and blood vessels.

In an open head injury, there can be skull fracture and resultant tearing of the protective meninges surrounding the brain. This can result in focal compression and laceration of brain tissue, as well as destruction of brain vasculature. Focal effects of open/penetrating head injury can include the point of initial compression that results in contusion, and there can also be laceration of underlying brain tissue. Furthermore, any time the protective blood-brain barrier is disrupted, the brain is vulnerable to infection and toxic exposure.
In closed head injury, one mechanism for brain injury stemming from the physical forces associated with the trauma is the impact/compression of brain tissue inside the skull. At impact, momentum shifts the brain and can cause it to strike the interior of the skull. This creates a bruising (contusion) at the site of impact. The brain might then rebound and impact backward to injure a second site of contusion opposite the primary point of impact. The initial injury is referred to as the coup injury, whereas the injury opposite the point of impact is referred to as a contrecoup injury. Focal contusions are generally more likely to occur in the frontal and anterior temporal regions of the brain due to the bony extrusions of the cranium in those regions (Yeates, 2000). As the brain compresses and stretches, this energy can result in stretching and tearing of nerve fibers, particularly along the axon, which can result in more diffuse damage, which is in addition to focal damage caused by contusion.

If the impact causes the head to turn or twist, the force of impact can cause the brain to rotate inside the skull. At points of impact with the skull, this can again cause contusion, and these rotational forces can also stretch brain tissue to the point of rupture and shearing. Although contusion creates focal injury to the brain, axonal stretching and shearing results in more diffuse damage that can be degenerative in nature, cause metabolic changes within the brain, and ultimately result in cell death (Bigler, 1997). Stretching, shearing, and cellular degeneration are not always immediately visible on CT or MRI scans, because these occur at a cellular level that is currently beyond the resolution of these standard imaging techniques.

Neuropathology stemming from TBI can be categorized as primary or secondary. Primary injuries to the brain are directly related to the physical forces involved in the trauma, including acceleration-deceleration and rotational forces. Acceleration–deceleration occurs when the head is moving and then stops suddenly. For example, a fall in which the head strikes the ground or motor vehicle accident results in extremely rapid deceleration of the head and brain. A rotational injury occurs when the brain continues moving inside the skull in a nonlinear fashion after the head has stopped. For example, a side impact motor vehicle accident might result in angular acceleration-deceleration that causes the brain to twist inside the skull.

Secondary effects of the brain trauma include brain swelling, mass effects created by a hematoma, cerebral edema, and increased intracranial pressure. Any of these conditions create a situation in which oxygen is restricted from being delivered to brain tissue (hypoxia), which can lead to further damage or even death (Bruce, 1995). Seizure activity is another potential secondary effect of TBI, and children tend to be more likely to develop posttraumatic seizures compared to adults (Baron, Fennell, & Voeller, 1995).

Finally, later emerging effects of the injury can create a host of additional challenges for the student who has experienced a TBI. Biochemical changes following a brain injury can extend over a lengthy period of time (Novack, Dillon, & Jackson, 1996) and can exacerbate hypoxic and ischemic damage that is already occurring due to primary and secondary effects of the injury. Later occurring effects of TBI can include white matter degeneration with associated cerebral atrophy and ventricular enlargement, as well as posttraumatic hydrocephalus (Bigler, 1997).
Severity of Brain Injury
It makes intuitive sense that the severity of brain injury tends to correlate with outcomes. Specifically, the greater the extent and severity of brain injury, the poorer the outcome is likely to be. This trend is generally true for all neuropsychological and functional domains. Even a mild TBI can result in a disruption of neuropsychological function, especially in attention and memory (Semrud-Clikeman, 2001).

The effects of mild TBI in children are not entirely understood, and my clinical experience suggests that individual variability and the dynamic nature of recovery of function in the weeks and months following the TBI cloud the issue. Although a loss of consciousness has long been a popular marker for the presence of even a mild TBI, recent evidence indicates that measurable neurocognitive abnormalities are evident immediately after sports-related concussions without loss of consciousness (McCrea, Kelly, Randolph, Cisler, & Berger, 2002). Many of the difficulties that are common reasons for referral for neuropsychological evaluation following mild TBI, such as deficits with attention and memory, are extremely difficult to quantify in an ecologically valid manner. Attention and memory involve fluid functional processing that does not necessarily culminate in an easily measured endpoint. For example, it can certainly be the case that a child performs adequately in the clinic setting on purported tasks of attention and memory, whereas, at the same time, the child clearly exhibits difficulties with these functions in everyday life. In my judgment, too often, true areas of weakness are dismissed because a child performed adequately on a particular test, when the power of the test to replicate the demands of a classroom environment and to subsequently predict everyday functioning is limited.

Although school-age children and adolescents who have sustained moderate to severe traumatic brain injuries sometimes recover certain functions to the point of earning average scores on standardized academic tests, this does not translate into average academic performance in the classroom (Ewing-Cobbs, Fletcher, Levin, Iovino, & Miner, 1998). The neuropsychology literature has tended to focus on very specific skills without capturing the range and interdependence of competencies required for successful classroom performance. Cognitive and behavioral outcomes are not necessarily highly correlated with one another after traumatic brain injuries in children (Eisenberg, 1990; Fletcher et al., 1996; & Fletcher, Ewing-Cobbs, Miner, Levin), which suggests that there are functions critical to school success that are not adequately tapped by traditional neurocognitive assessments.

Age at the Time of Injury
In addition to the severity of the TBI, the age at the time the injury is acquired is an important variable that impacts neuropsychological outcomes. There tends to be a popular assumption that children who sustain a brain injury earlier in life tend to have a better outcome because their brain has time to reorganize functions. In other words, the brain is considered malleable such that other brain regions can compensate for areas that have been rendered dysfunctional by injury.

Although this notion holds true to an extent in that certain functions can reorganize after damage (Kolb & Gibb, 1999), this reorganization is typically not without functional cost. Students who experience TBI earlier in life tend to have poorer outcomes across most neuropsychological domains, and more significant cognitive impairment tends to be seen in children who are injured prior to age 13 (Bigler, 1997). Furthermore, younger children appear to demonstrate a slower
rate of change over time and more significant residual deficits after reaching a plateau in functional recovery from TBI, as compared to older children with injuries of similar severity (Ewing-Cobbs et al., 1997).

There are few studies that evaluate long term academic functioning following TBI in children, but those that do tend to identify persisting difficulties in areas including word decoding, reading comprehension, spelling, arithmetic, and written language skills (Barnes, Dennis, & Wilkinson, 1999; Ewing-Cobbs et al., 1998; Taylor et al., 2002; Wrightson, McGinn, & Gronwall, 1995). Ewing-Cobbs et al. (2004) used individual growth curve analysis in a longitudinal design and found a robust relationship between injury severity and rate of growth of academic skills over time in that more severe injuries were associated with a slower rate of academic skill acquisition. This study also found deceleration of academic growth curves in younger children with mild/moderate and severe TBI, consistent with the hypothesis that the interruption in development during the formative years places a child at additional risk for neuropsychological deficits beyond those that are the direct result of the brain injury.

Younger age at the time of injury has also been implicated in the occurrence of later onset deficits. Although the issue has not been thoroughly researched, the idea is that early brain injury may disrupt functional neural networks that will later be responsible for higher cognitive functions such as complex problem-solving, abstract thinking, impulse inhibition, and cognitive flexibility. Because these functions do not fully develop and become functional until adolescence and young adulthood, these deficits are not appreciated until these functions are tapped. Indeed, younger age at injury has been demonstrated to increase risk for impairment of executive functions—functions associated with abstract concept formation, self-regulation, and impulse control (Slomine et al., 2002).

**Effects of TBI on Specific Neuropsychological Domains**

IQ tends to decline as a function of severity of injury, although there can be relatively rapid recovery of IQ during the initial months of recovery from the brain injury (Semrud-Clikeman, 2001). However, gains in IQ back toward baseline can be misleading, as difficult-to-measure information processing functions, such as memory, mental processing speed, and attention are not necessarily fully captured as part of IQ. Therefore, a student may appear to perform reasonably well on a standardized IQ test and, at the same time, have a number of functional weaknesses that significantly interfere with academic success.

Language functions are frequently interrupted following TBI, even if the injury does not occur in the language areas of the brain (Yeates, 2000). The diffuse effects of the brain injury appear to be related to persistent difficulties with basic linguistic functions, such as oral language comprehension, word-finding, and oral language fluency. These functional deficits may not be apparent during casual interactions with the student, which can result in misleading conclusions regarding the student’s expected competence on assignments requiring significant language comprehension as well as written and oral expression.

Memory functions are also at significant risk following a TBI (Semrud-Clikeman, 2001; Yeates, 2000). As with other neurocognitive domains, disruption of memory functions tends to correlate with severity of the TBI, such that more severe memory deficits typically result from more
severe injuries. It also makes sense that one needs to consider other functional deficits when examining apparent memory problems in students with TBI. For example, problems with attention, mental processing speed, or oral language comprehension may limit the amount of information a student is able to take in, thus placing a ceiling on the amount of information the student is subsequently able to store and later retrieve.

As noted above, attentional problems are common following TBI (Catroppa & Anderson, 2003), and younger age at time of injury as well as injury severity tend to be associated with poorer attentional outcomes. This area has been difficult to research, however, because of the fluid nature of attention and the lack of ecologically valid objective measures of attention that can be administered during an evaluation. Instead, attentional deficits seem best captured by observational information from those working closely with the student. Deficits in areas such as mental processing speed, oral language comprehension, and memory have many symptoms that mimic attentional problems; therefore, these functions need to be carefully evaluated and teased apart in order to identify the most appropriate point for intervention.

Sensory and motor functions can also be disrupted following TBI, depending on the location and nature of the injury. Deficits in these domains have significant educational implications for activities, including independent ambulation, speed of navigation from one area of the school to another, and handwriting. If there are speed demands, such as a limited amount of time between classes or a requirement to take notes in a lecture class, deficits in sensory and motor functions can create frustration and interfere substantially with the student’s ability to keep pace academically with peers.

Unique Problems Associated With Assessing TBI
Because of the heterogeneity of outcomes associated with TBI and the effects of mediating variables, such as age at the time of injury, severity of the injury, and the time since injury at the time of assessment, students with TBI pose a particular challenge when assessing educational needs. In addition, variables that can be difficult to quantify must be considered carefully in educational programming for students with TBI, as these symptoms can significantly impact the student’s success in school.

Time since injury is a factor that creates a unique problem for educators assessing the needs of students who have experienced a TBI. Longitudinal studies indicate that children typically exhibit a gradual recovery over the first few years following the injury, with the most easily observable improvement occurring in the time soon after the injury. Thus, it is imperative that the assessment of needs and subsequent educational planning take into consideration the time that has elapsed since the injury. For example, the assessment of educational needs for a student for whom several years have elapsed since the TBI can more safely assume that the educational assets and deficits that the student exhibits are relatively stable and the pattern is likely to be relatively chronic. However, during the first year after injury, and particularly in the first few months after TBI, the assessment strategies need to account for the fact that the student is still in a phase of measurable functional recovery, and that needs identified during assessment at one point in time may not be relevant for the long term. It is, therefore, important for assessment personnel to plan for serial evaluations of the child’s functioning, though this does not
necessarily need to include formal testing. Rather, frequent contact with teacher and parent, as well as repeated student observation, can form the basis of appropriate serial evaluations.

Similarly, the education plan that is developed for a student who is still recovering from TBI must be revisited with sufficient frequency to ensure that the plan is based on an up-to-date assessment of needs and that the plan continues to appropriately target the student’s needs.

As noted above, the age at the time of injury must also be considered when beginning an assessment. A child in elementary school may initially appear to recover and perform adequately in the classroom. However, as curriculum demands increase over the years and place additional demands on higher cognitive functions (e.g., deductive reasoning, inferential thinking, organization, comprehension and retention of greater amounts of written material), the child may increasingly have difficulty performing successfully (Savage, 1991). Because so much time has passed between the injury and the onset of apparent difficulty and because the child is no longer under medical management for the brain injury, parents and educators may fail to realize the correlation between the injury and the performance deficits. In this case, attributions for the symptoms might develop that do not reflect the relationship between the student’s educational needs and the TBI, and this might lead to faulty interpretation of needs and improper educational programming. By understanding the nature of a child’s TBI, as well as the developmental challenges and transitions that a student faces, points of particular vulnerability (e.g., the transition from elementary to middle school) can be more closely monitored for the later expression of deficits secondary to an earlier TBI.

The numerous relatively common symptoms that are difficult to quantify present another challenge to those charged with identifying the educational needs of students who have experienced TBI. For example, symptoms such as headaches, fatigue, dizziness, and sleep disturbance are common following TBI and may have a significant negative impact on educational performance. However, these physical concerns are not easily measured or quantified. Because of this, these symptoms may not be fully accounted for in the educational planning, which can result in significant needs being overlooked.

Cognitive sequelae can also be difficult to quantify in the traditional sense. My experience has been that this can lead to an inadequate appreciation for the validity of the symptoms, and it may result in inadequate planning for these deficits. Complaints (e.g., slower mental speed, disorganization, difficulty with impulse control, distractibility, forgetfulness) do not have “tests” that capture the deficits in a manner that is necessarily ecologically valid and fully predictive of future performance. In other words, a student may perform satisfactorily in an individual testing session on measures purported to capture these functions, but performance in the testing session may not predict the student’s functioning in a busy and stimulating educational setting.

Social, emotional, and behavioral disturbances following TBI may present difficult-to-quantify deficits that severely interfere with educational success. Again, because these symptoms are not reflected by a score on a test, these symptoms may not necessarily be fully appreciated as stemming from the TBI, which results in educational programming that is not adequate to address these needs. Examples of these difficulties include irritability, low frustration tolerance, temper outbursts, apathy, trouble with initiation, mood regulation problems, and lack of insight regarding personal limitations.
If the broad range of common and possible sequelae of TBI is understood by those responsible for the assessment of needs and for the educational programming for these students, there is less likelihood that the needs of students with TBI will go unmet. Assessment personnel need to be prepared with assessment strategies that go beyond traditional objective tests. Observation, parent and teacher report, and the student’s record of performance need to be considered as valid pieces of assessment information that should feed into educational programming decisions. The inadequacy of current tests to fully measure and predict functions in everyday life should not be the basis for failing to recognize educational needs in students with TBI.

**Using Assessment Data for Hypothesis Testing and Intervention**

Because of the long tradition of neuropsychological assessment as involving localization of function to areas of the brain, it is tempting to employ a cookbook approach to assessment in which specific locations of damage are related to specific functional deficits. Although this holds true to an extent, the interdependence of functional neural systems is far more complex and is not captured by this approach. Although it is important that assessment specialists working with students with TBI have a good working knowledge of functional deficits typically associated with certain areas of the brain, it is equally important that the full spectrum of cognitive, behavioral, academic, social, and emotional sequelae be appreciated. It is more important that assessment staff be good problem identifiers and competent in generating and testing hypotheses in order to plan reasonable and data-based interventions for students with TBI.

During the evaluation of needs phase, it is important to consider all available information when planning assessment strategies. The nature, extent, and severity of injury need to be considered. Variables such as the age of injury, time since injury, and the current developmental cognitive and educational demands need to be taken into account. The student’s competencies and strengths provide essential information that will play an important role in developing appropriate interventions. The student’s family support network and resources need to be understood, as these can also potentially facilitate or hinder educational success following TBI.

The most fruitful information regarding educational needs and adjustment following TBI comes from observation, parent and teacher report, and the student’s record of performance. Within the context of injury variables and current demands on the student, this essential information forms the foundation for hypothesis testing that drives more traditional testing. The information provided by parents, teachers, and others who have worked with or treated the student during recovery from TBI helps assessment personnel to develop questions that might be answered with formal testing. For example, if concerns are posed with regard to executive functions following TBI, tests of executive function might be administered to assist in better understanding the boundaries of the deficits as well as any conditions under which the student demonstrates adequate or preserved functioning.

When a student exhibits an area of deficit in any domain of educational functioning, the assessment staff should consider the hierarchy of functions required to perform the skill. This hierarchy can target the assessment to areas of suspected weakness, which may lead to appropriate remedial strategies and/or appropriate accommodations. For example, if concerns are raised with regard to memory functioning, the necessary components to successful memory need to be considered in hierarchical order so that the nature of the weakness can be identified.
Memory for information requires successful acquisition, storage, and recall of information, but the process can break down anywhere in the sequence. Some children have apparent memory deficits that are actually attention problems that prevent acquisition of information. Other children attend to information adequately, but may have information processing deficits (e.g., language comprehension) that prevent information from being encoded reliably. Still other students are unable to retain information over time such that they are unable to retrieve the information. Retrieval deficits may actually be working memory deficits, problems with executive functioning, or specific expressive language deficits. Thus, in a domain as apparently simple as memory functioning, there are many areas of potential breakdown of function, and this can only be elicited through careful testing of hypotheses about the performance weakness in order to identify where the function is failing. Once this area of deficit is identified, intervention strategies can be developed that appropriately target that deficit.

Conclusion
Although neuropsychological assessment data have proven sensitive in detecting cognitive deficits after TBI in children (Yeates, 2000), the field has a long way to go before it can adequately predict educational outcomes in students with TBI. The information gathered through neuropsychological assessment can be very helpful in guiding the identification of cognitive assets and liabilities, but broader consideration of factors that determine educational success needs to occur. To date, most neuropsychological outcome studies focus on standardized academic achievement scores as the primary educational outcome variables (e.g., Ewing-Cobbs et al., 2004). Others focus on placement in special education (e.g., Miller & Donders, 2003).

Academic success has multiple determinants. At the same time, the factors that underlie poor academic performance in students with TBI are equally multidimensional and require collaborative efforts among disciplines. Pediatric neuropsychology research focusing on TBI outcomes would do well to better reflect the knowledge base accrued by special educators working with and researching outcomes and interventions with students with TBI. At the same time, advances in research methodology in pediatric neuropsychology will help increase the understanding of the neural bases, developmental trends and trajectory, and interrelationships between different processing domains following TBI. This can provide a conceptual basis on which rehabilitation and educational interventions can be hypothesized, developed, and tested, which ultimately achieve the shared goal of improving functional outcomes for children with TBI.


REFERENCES

