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Chapter 11b

Adult outcomes of pediatric traumatic brain injury

Miriam Beauchamp, Julian Dooley and Vicki Anderson

Introduction

Traumatic brain injury (TBI) is one of the most common causes of acquired disability during childhood. While the majority of such injuries are mild, and result in few, if any, functional sequelae, children sustaining more significant insults may experience permanent cognitive and behavioral deficits. Clinical reports indicate residual impairments in a range of skills, particularly information-processing, attention, memory, learning, social function and behavior. These deficits impact on a child's capacity to interact with the environment effectively, resulting in lags in skill acquisition, and increasing gaps between injured children and their age peers, as they move through childhood and into adulthood. Secondary deficits may also emerge, relating to family stress and adjustment difficulties. Treatment and management of the child with TBI and family requires long-term involvement, where the role of the neuropsychologist is to understand the child's difficulties, to inform parents and the wider community of their cognitive and behavioral implications, to liaise with teachers and rehabilitation workers, to design academic and vocational interventions and behavior-management programs, and to provide counseling with respect to adjustment issues for the child and family.

Epidemiology

Population-based studies have recently reported that 750:100 000 children will suffer TBI each year. Of these, fewer than half will seek medical care, 10% will be hospitalized and only 7% will sustain significant head injury [1]. Between 5 and 10% will experience temporary and/or permanent neuropsychological impairment, and 5 to 10% will sustain fatal injuries [2]. When considering adult outcome from such insults, it is frequently assumed that only children with more severe injuries will continue to experience significant sequelae long-term after insult. Examination of data specific to this severe injury group shows that the mortality rate is approximately one-third, with another third of children making a good recovery, and the last third exhibiting residual disability, at least in the first few years post-injury [3]. To date, very few studies have followed injured children into adulthood to document the frequency and nature of any ongoing deficits.

When considering the long-term impact of TBI in childhood, there are several factors that must be considered, some of which are specific to this particular stage of the life cycle. First, and as for adults, more severe insult is consistently associated with poorer prognosis [4]. In addition, children sustaining TBI are not representative of the population. Boys are more than twice as likely to suffer a TBI [1]. Further, TBI is more common in socially disadvantaged children [5, 6] and in children with pre-existing learning and behavioral deficits [7]. These pre-existing characteristics may increase the young person's risk of experiencing post-injury problems and limit their capacity to access necessary rehabilitation and educational resources, resulting in slower than expected recovery and development and likelihood of residual impairments through childhood and into adulthood. Finally, age is also a key predictor [4], with the nature of pediatric TBI varying with age. Infants are more likely to sustain injury due to falls or child abuse. In fact, infancy is the only developmental stage with a high rate of non-accidental injury, which commonly results in more severe injury and higher mortality and morbidity than accidental injuries [8]. Older children and adolescents are more commonly victims of sporting, cycling, and pedestrian accidents, and assaults.

Pathophysiology

TBI is usually due to a blow or wound to the head, sufficient to cause altered consciousness, and may be classified as penetrating (or open) head injury or closed head injury. The mechanics and underlying pathophysiology of these injuries will differ, depending

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on the cause of injury, and the degree of the force involved, and may result in a range of possible outcomes. Pathophysiology may be classified according to characteristics of the insult: (i) *primary impact injuries* occur as a direct result of force to the brain, and include fractures, diffuse axonal damage, contusions, and lacerations. Such injuries are generally permanent, and show little response to early treatment; and (ii) *secondary injuries*, such as extradural, subdural, and intracerebral hemorrhage, may result from the primary injury, and are predictive of poor outcome in children [9]. Raised intra-cranial pressure, brain swelling, hypoxia, infection, and metabolic changes, including hypothermia, electrolyte imbalance, and respiratory difficulties may also occur [10]. If not treated quickly, usually via surgical intervention, these secondary complications may cause cerebral herniation and ultimately death. Recent investigations have found that secondary damage may also result from neurochemical processes. Elevated levels of excitatory amino acids, such as glutamate and aspartate, have been detected in cerebrospinal fluid immediately post TBI, and found to persist for several days, causing disruption to cell function, and eventual cell death [11].

Penetrating injuries account for approximately 10% of all childhood TBI, and refer to injuries which involve penetration of the skull by some form of "missile". Injury tends to be localized around the path of the missile, with additional damage resulting from skull fragments or shattered fragments from the missile itself. Secondary damage may occur due to cerebral infection (from the alien object entering the brain), swelling, bleeding, and raised intra-cranial pressure. Loss of consciousness is relatively uncommon, but neurological deficits and post-traumatic epilepsy are frequently observed. Neurobehavioral sequelae tend to reflect the focal nature of the insult, and children often exhibit specific deficits consistent with the localization of the lesion, with other skills intact.

Closed head injury is more common and refers to an insult where the skull is not penetrated, but rather the brain is shaken within the skull cavity, resulting in multiple injury sites, as well as diffuse axonal damage. Damage results from compression and deformation of the skull at the point of impact. The primary pathology includes contusion, or bruising, at point of impact of the blow and at other cerebral sites. Specific areas of the brain are particularly vulnerable to such damage, including the temporal lobes and basal frontal regions. The characteristic pattern of neurobehavioral consequences reflects involvement of these regions, and includes impaired attention, processing speed and executive abilities.

Functional manifestations

Consequences of adult TBI are well established, with findings indicating significant problems (physical, cognitive dysfunction, educational, vocational opportunity, psychological) persisting even several decades post-injury, and including social and psychiatric disturbance [12, 13]. In comparison, the long-term consequences of childhood TBI remain poorly understood. One of the major difficulties faced by professionals working with children with TBI is predicting outcome and determining priorities for intervention and follow-up. Some researchers argue for the presence of serious and persisting sequelae, even after the mildest of insults; however, opportunities to follow these children into adulthood are limited, and it is likely that clinical perceptions of long-term outcome may be negatively skewed, with only those children with severe ongoing problems presenting for services in the long term post-injury.

To date, only a handful of studies have followed survivors of childhood TBI into adulthood, with somewhat conflicting results, possibly due to inherent methodological problems of longitudinal research, including sample attrition and bias and changes in diagnostic and treatment approaches over time. While only a few studies have reported on adult outcome after mild TBI in childhood, results are consistent, and suggest very few long-term neurobehavioral consequences [14, 15], although psychological problems are more common [16, 17].

In contrast, there is a growing body of research addressing adult outcome from more severe TBI in childhood. Even in these studies reports of gross neurobehavioral impairment are rare, and most survivors tend to manage adequately through their school years [18, 19]. Where cognitive problems are detected, they tend to be in the more dynamic domains of attention, memory, and processing speed [20–22]. Persisting medical and physical problems are more common [17, 23], as are vocational and educational difficulties [13, 17, 18, 22]. Social and psychiatric problems are, however, the most highly represented and include social maladjustment and isolation, poor quality of life, depression, attention deficits, and family problems

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Table 11b.1. Functional characteristics of adults with childhood TBI.

Cognitive difficulties	Attention Processing speed Executive deficits
Psychiatric disorders	ADHD Depression Adjustment disorder
Adaptive disorders	Academic failure Unemployment
Social problems	Isolation Low rates of participation

[13, 17, 21], with an association between both pre-injury factors and injury severity and presence of difficulties. See Table 11b.1 for a list of the common functional characteristics of adults with childhood TBI.

Outcome from child TBI is highly variable, and a number of factors have been established as contributing to recovery, at least up to 5 years post-insult: injury severity and injury age, pre-morbid characteristics of the child and psychosocial factors [4, 14, 23]. Other factors of potential importance include access to rehabilitation and other resources, child and family adjustment and degree of residual disability [4, 24]. The limited body of research addressing long-term effects of childhood TBI suggests that similar factors may be relevant for long-term outcome [22, 25], although the research emphasis has been almost entirely on injury-based predictors to date.

Assessment of neurobehavioral outcomes and functional abilities

Neuropsychological assessment plays an important part in the diagnostic, recovery and rehabilitation processes post-TBI, and the characteristics of such childhood assessments at the acute stage are described in Chapter 11a.

Assessment is more frequent and long-term for severely injured individuals who suffer serious deficits that impact significantly on their ability to function in daily life. Ongoing assessment of function is necessary to track the development of cognition post-injury and to identify changing needs as the brain recovers and environmental demands change (e.g. re-integration to school or work). This is true for the post-acute phase, but is equally important in the very long term. Though cognitive deficits usually improve during the 2 years post-injury in children, recovery plateaus after this time and remaining deficits will continue to impact on functioning into adulthood [26, 27]. Survivors of pediatric TBI may even appear to make a full recovery in the initial stages post-injury, with "latent" TBI symptoms emerging only months or even years after injury as later developmental milestones are attained [28].

Neuropsychological assessment is of benefit throughout the lifespan. By the time individuals injured during childhood reach early adulthood, they are generally well aware of the lasting effects of their injury on various spheres of their lives. As they move through the transitions to adulthood, it may be necessary to re-evaluate their capacity to cope, both cognitively and emotionally, with new demands and responsibilities. For example, a change in employment may cause new challenges by tapping previously unused skills or by increasing cognitive demands. Difficulties in dealing with such changes may require an assessment to identify areas of dysfunction and how these may be compensated so the individual can better manage their new environment.

Neuropsychological outcomes after childhood TBI are partially a function of brain plasticity. Long-term evaluation therefore requires an understanding of neural reorganization, maturation and degeneration, as well as their interaction with developmental growth and experience. Contrary to traditional views, findings now indicate that infants and children who sustain severe injuries are particularly vulnerable to residual cognitive impairments [4]. Long-term follow-up, monitoring and management is of particular importance for these at-risk individuals. Although some restoration of function may occur, the late appearance of cognitive and behavioral problems may be associated with a failure of particular brain regions (and their associated cognitive skills) to develop, either as a direct result of TBI or due to progressive atrophy or loss of neural activity [28, 29]. These processes may lead to atypical patterns of cognitive function due to structural and functional re-assignment in the injured brain. Accordingly, individuals who demonstrate similar performance levels on a particular test may in fact be relying on different neural substrates. This suggests that assessments in the long term should rely on refined methods capable of detecting subtle cognitive variations and compensation strategies.

The unique characteristics of adult outcomes of childhood TBI have consequences for the goal and

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structure of remote neuropsychological assessment, which must be considered as distinct from the early, post-acute and developmental evaluations following injury and different to the acute assessment of mature adults who sustain injuries. Some of the objectives of these 'late' assessment may include: (a) developing an up-to-date cognitive profile in keeping with the patient's environment; (b) identifying "chronic" neuropsychological impairments; (c) re-assessing cognitive, behavioral and social functions in light of adult milestones and evolving roles and responsibilities; (d) tailoring assessment to pinpoint subtle areas of dysfunction; (e) generating cognitive strategies to assist with daily life; and (f) investigating the potential effects of brain plasticity and the role of reorganization/recruitment for cognitive and behavioral function.

In keeping with a shift in goals, there is also a shift in focus when conducting neuropsychological assessments in adults with childhood injuries. As in the acute phase, testing in the long term remains an individualized undertaking, tailored to the needs and characteristics of the client; however, these types of evaluations have their own qualities. First, long-term follow-up assessments need to be specific and sensitive, as the major areas of difficulty for the patient will have been previously identified. Second, the clinician needs to be aware that subjective complaints and self-reports of daily functioning may be greatly influenced by compensatory strategies established over the years post-injury, as well as habituation to existing deficits. In this sense, a lack of subjective complaints may not accurately reflect absence of cognitive dysfunction (nor lack of insight), as adults may have developed adaptations and compensatory mechanisms which mask the nature and extent of existing problems. Third, age at injury is an important consideration, as it will affect the extent and nature of the neurocognitive skills likely to have been affected by brain injury. Donders and Warschauwsky [30] demonstrated that early-onset childhood TBI results in worse outcomes in higher-level cognitive skills and social integration than later "transition age" (17–21 years) injuries. The relative impact of TBI on cognitive and social skills is a function of the stage of development at injury; skills that are emerging and not yet solidified may be particularly vulnerable to trauma. Fourth, the ongoing review of the impact of childhood TBI into adulthood may need to rely increasingly on measures that reflect real-life skills and behavior in order to address the daily impact of chronic TBI sequelae. There is increasing interest in the ecological validity of the neuropsychological assessment, though adequate measures are still scarce [31, 32]. Results obtained within the confines of a standard assessment need to be interpreted with a consideration of real-world environments which can be chaotic and noisy and hence more difficult for individuals with brain injuries to negotiate. Obtaining an adequate history and information from third parties can help in achieving an accurate picture of an individual's functioning in the real world [33].

Cognitive assessment

The evaluation of cognitive function remains the cornerstone of neuropsychological assessment at any stage post-injury and at any age. Identifying mental strengths and weaknesses is of fundamental importance to providing individuals with brain injury and their families with an accurate depiction of their current abilities. Neuropsychological assessment in the long term following childhood TBI should continue to be based on individualized systemic evaluation of cognitive skills. Measurement of IQ is still useful to obtain an up-to-date representation of global intellectual functioning. In order to minimize overuse of full IQ scales abbreviated IQ tools can be helpful (e.g. Wechsler Abbreviated Scale of Intelligence) [34]. Using standardized measures of cognitive function, particularly those that are applicable to wide age brackets, procures the advantage of providing scores that can be compared across the lifespan from one assessment to another, enabling the neuropsychologist to track change over time. However, practice effects should be considered when interpreting results from individuals exposed to multiple assessments over the years, particularly when these are conducted in relatively short time spans, even when efforts are made to use alternate forms of tests.

Specific cognitive domains of interest include attention, memory and learning, processing speed, executive function, visuospatial and visuomotor skills, language, reading, and mathematics. Though standardized assessments exist for most of these areas, the need for a more specific and subtle evaluation in the long term suggests that it will be useful for the clinician to carefully choose particular tests which are valid and reliable and that span child and adult age bands such as the Test of Attention [35], Delis-Kaplan Executive Function System [36], the Wechsler Memory Scale-III [37], and the Wechsler Individual Achievement

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Test-II [38]. Measures that focus on specific cognitive domains may also be included: memory (California Verbal Learning Test-II [39]; Rey Auditory Verbal Learning Test [40]); attention (Continuous Performance Test-II [41]; Paced Auditory Serial Addition Test [42]), executive function (Rey-Osterreith Complex Figure [43]; Wisconsin Card Sorting Test [44]; Stroop Test [45]; Verbal Fluency Test [46]).

Vocational assessment

Research findings demonstrate that injuries sustained during childhood affect vocational outcome. Ewing-Cobbs and colleagues [47] found that almost 50% of patients with TBI failed a school grade or required placement in special education classrooms and the odds of unfavorable academic performance were 18-times higher for patients versus controls. Such poor academic success has significant implications for later vocational outcomes. Koskiniemi and colleagues [48] further showed that, following preschool TBI, normal school performance or intelligence does not necessarily translate to good vocational outcome, suggesting that almost any child with brain injury may be at risk for professional problems or unemployment. In light of these findings, assessment of vocational status is an important element of neuropsychological assessment in adulthood.

TBI survivors in full-time employment demonstrate better intellectual capacities, fewer executive deficits [19, 49], as well as largely intact perceptual, complex visual processing, attention and memory capacities [50, 51], suggesting that assessment of these skills is an important aspect of the neuropsychological evaluation of vocational outcomes. While such cognitive factors are of a fundamental importance in determining an individual's ability to undertake and maintain full-time work, research also shows that they cannot alone predict vocational outcome. Environmental demands and social and emotional factors are also critical when determining the need for vocational rehabilitation and support [52–54]. Self-awareness, in particular, has been identified as an important factor in successful return to work and should therefore be considered as related to vocational success [55].

Emotional, social and behavioral assessment

There is increasing evidence that after childhood TBI, social and emotional deficits increase and persist into adulthood, having unfavorable effects on daily living, ability to engage in work and social activities and coping with adult responsibilities. These difficulties may be exacerbated by accumulated failures and frustrations throughout development, which may cause survivors to withdraw from regular work and leisure activities and to accumulate significant emotional problems. As noted previously, available research has identified social and psychological problems as the major complaint of adult survivors. Yeates and colleagues [56] suggest that these difficulties are related to executive abilities, pragmatic language and social problem-solving skills, and are important in determining social functioning throughout the lifespan post-TBI. Measures of social functioning are often limited to general, parent-based reports, which are not useful with adults. Few of the existing measures are standardized and no appropriate tools exist for evaluating the long-term social implications of TBI into adulthood. Some measures that may be of use for evaluating adaptive, functional and psychosocial outcomes in adults are the Community Integration Questionnaire [57] and Sydney Psychosocial Reintegration Scale [58]. Also, the Dysexecutive Questionnaire, part of the Behavioural Assessment of the Dysexecutive Syndrome [59], can be useful for identifying everyday signs of executive problems which may impact on social and behavioral function.

TBI is also associated with a high rate of emotional and behavioral problems in adulthood including increased anxiety, depression and poor coping skills [60–62]. Maladaptive behaviors are related to the psychiatric sequelae of pediatric TBI, which have become an important focus of the evaluation of TBI outcomes in the long term. Although some patients suffer from lifetime psychiatric disorders, there is also evidence for the emergence of novel disorders, particularly following severe injury during childhood. Bloom and colleagues [63] reported that attention deficit hyperactivity disorder and depression are the most common novel diagnoses, though a variety of psychiatric diagnoses may be present, with 74% of disorders persisting in 48% of injured children. Post-injury personality disorders have also been identified in a high proportion of TBI survivors (66%), though there does not appear to be a TBI-specific personality syndrome given that common post-TBI disorders range between borderline, avoidant, paranoid, obsessive-compulsive and narcissistic personality types [64]. Given the prevalence of both Axis I and II psychiatric diagnoses following childhood TBI, an initial screening of such

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disorders and of more general emotional and behavioral problems (e.g. Minnesota Multiple Personality Inventory-2) [65] can be useful when frank psychiatric problems are suspected and to evaluate the need for further referral for full psychiatric evaluation using structured clinical interview techniques to complement the neuropsychological profile of cognitive, social, and emotional abilities.

In summary, neuropsychological assessment is important for the life-long management of childhood TBI-related dysfunction and ongoing monitoring of recovery, adaptation and compensation as a function of fluctuating environmental demands and responsibilities. Assessment of childhood TBI in adulthood is distinct from evaluations performed acutely and brings with it a number of challenges and particular considerations. Evaluations must make allowances for ongoing development and aging, reorganization of structure and function, compensatory mechanisms and habituation, practice effects, real-world functioning, changing life situations and the demands of the current environment. Thorough assessments remain important, though there may be a shift in focus from cognitive domains to the evaluation of social, emotional and behavioral problems, as well as vocational outcomes and adaptive capabilities. Continued collaboration with other health professionals remains essential as well as ongoing referral to rehabilitation and intervention programs when needed.

Interventions

Recently, significant advances have been made in evidence-based, acute medical care and diagnostic technology used to assess the extent and severity of TBI, but the status of knowledge with respect to behavioral interventions is much less developed, and there have been relatively few studies which have addressed child-based post-acute rehabilitation and long-term intervention specifically. A wide variety of strategies have been used to treat post-TBI impairments in adults, with similar techniques generally reported within child populations. Within clinical contexts, rehabilitation models are traditionally multidisciplinary, taking a holistic view of the patient, and employing an eclectic range of treatments. Commonly, these interventions are not confined to evidence-based methods. Within such contexts, the neuropsychologist's role is often focused on specific evidence-based models, which are frequently domain-specific (e.g. attention).

There is little empirical evidence detailing the treatment of post-TBI impairments in children and adolescents that can be of use to clinicians. Navigating the comparatively sparse intervention literature is made difficult due to a number of factors that influence a clinician's ability to effectively evaluate studies: the heterogeneity of patients and their differing pre-injury characteristics, length and type of intervention used, degree of injury severity, sites of brain damage, timing of assessments, methods of data collection, and the outcome measures used. The majority of intervention studies include only adults, although it is clear that outcome after TBI is different for children than for adults. Further, much intervention research is based on single-case or small group designs, limiting the generalizability of results. Consistent with this, Teasell and colleagues [66] reported that across all ages, less than 30% of studies used randomized controlled trial (RCT) designs.

Cognitive interventions

A number of approaches have demonstrated success in treating cognitive impairments in children with TBI. In one such study, involving both adult and child survivors of TBI, Wilson and colleagues [67] used a pager system to treat post-TBI memory and planning impairments. Their randomized control cross-over study was structured so that patients were allocated to a pager or wait list group before choosing what they wanted to be reminded about. After 5 weeks with the pager, participants achieved over 70% of their tasks compared with less than 50% for the wait list group. A follow-up assessment 7 weeks later demonstrated that the pager group still achieved significantly more tasks than they did at baseline, indicating that the pager system performed well even after completion of the training program.

Similarly, Suzman et al. [68] used an intervention consisting of several training "modules" focusing on metacognitive, self-instructional, self-regulation training, attribution and reinforcement, and administered using a computerized problem-solving program. The authors reported substantial gains on trained tasks, as well as improvements on some of the post-intervention standardized tests of problem-solving. Clearly, the multi-focused approach to the treatment of post-injury cognitive impairments resulted in improved functioning in specific skills with a consequent run-on effect to other related skills. However, in this study, training consisted of three 40-minute

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sessions per week which lasted for over 3 weeks. Clearly, this level of time and commitment is not going to be suitable for many families. Other, more hands-off, approaches have been developed and appear promising. For example, preliminary evidence from a telephone-based cognitive training intervention study suggests that, in addition to improved neuropsychological performance, this approach also resulted in improved self-esteem ratings in children, having the additional benefit of enhanced feelings of task-mastery and motivation to face new challenges [69].

To date, most approaches to intervention have focused on more severe TBI, and have usually involved a considerable patient burden, in terms of time commitment. In contrast, in their intervention with mildly injured children and adults, Ponsford et al. [70], utilized a simple, efficient method, providing patients and their families with an information booklet, documenting the likely symptoms following minor injuries. They reported that behavioral symptoms and cognitive difficulties were reduced in children with mild TBI who participated in the intervention, compared to those in a control group. The authors reported that providing this information early in the treatment phase successfully reduced parent and child stress. Similarly, Kirkwood et al. [70] have presented preliminary evidence that for patients with mild TBI, provision of a comprehensive information booklet at acute presentation was as effective as a follow-up meeting with a clinician. Thus, there may be significant cost-effective benefits in educating parents on the commonly reported symptom presentation and resolution, at least with injuries at the mild end of the severity spectrum.

Emotional, social and behavioral interventions

Impairments in behavior and social functioning have been associated with parental stress, family turmoil, problems in school and impaired peer relations and, collectively, constitute the number one reason that families seek intervention and rehabilitation services [72]. In a recent review, Ylvisaker et al. [73] reported that the majority of studies since 2000 were based on a positive behavior intervention and support system using proactive, antecedent-focused strategies, and that, to date, only two such studies used RCT designs. For example, Wade et al. [74] successfully reduced problem behaviors in children with TBI, using a 6-month family-centered intervention, consisting of seven bi-weekly core sessions and up to four individualized sessions each lasting approximately 1.5 hours, and based on a proactive problem-solving approach. Medd and Tate [75] have also demonstrated successful outcomes for post-TBI anger problems using a variety of antecedent control procedures (e.g. self-awareness training) in individual therapy sessions with a clinical psychologist for 5 to 8 weeks. In this treatment, participants were required to keep a daily log of their aggressive outbursts, a task that is difficult for patients in general and especially those with prospective memory impairment.

Intervention strategies from the field of applied behavior analysis have proven somewhat successful in the treatment of post-TBI behavior problems. For example, Feeney and Ylvisaker [76] used photographic and written cues for desired behaviors, verbal rehearsal of plans, and a performance review with three adolescent patients with severe TBI. The strategy effectively reduced the frequency of aggressive and challenging behaviors but these improvements were not maintained once the cues were withdrawn. Other strategies have included the use of token economies [77], verbal contracts [78], reinforcement and informational feedback [79], initial reduction of task demands [80], caregiver education [81], stress inoculation training [82], extinction [83], and home-based mentoring [84]. All these intervention strategies have demonstrated success in treating post-TBI behavior problems.

In the first published study to describe an intervention targeting post-TBI emotion perception deficits, Bornhofen and McDonald [85] reported that participants significantly improved both in their ability to judge basic emotional stimuli and in the more complex task of making social inferences based on the demeanor of a speaker. These results are promising as it has been suggested that impairments in certain skills related to emotion perception, such as facial expression, vocal prosody and body posture [86–89], underlie the lack of improvement frequently observed in many patients with TBI.

Educational, vocational interventions

Educational and vocational difficulties are frequent post-TBI and have been reported to persist through childhood and into adulthood. Survivors of serious TBI often find it difficult to meet educational demands, and are at risk of leaving school early. As a

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result, further education opportunities are limited, and the range of potential employment contexts restricted. Many young people will need support in choosing appropriate careers and entering the workforce. Commonly, such support is provided based on the results of neuropsychological evaluation, which describes the young person's cognitive strengths and weaknesses, and assists in identifying employment contexts that meet these profiles. In some instances, survivors are able to utilize such information independently, and require no additional input. Where more serious difficulties are present, the neuropsychologist may become involved in consultations with employers or vocational counselors, and may even play a role in task analysis of job demands, in order to develop strategies to compensate for the individual's difficulties.

Hux and colleagues [90] found that nearly 29% of students with reported TBIs had received special education services. In addition to the post-TBI academic challenges, the biggest challenge reported by adolescents with TBI was reintegrating back into the classroom and school environment [91]. It is well established that impairments in cognitive or behavioral functioning are related to, and possibly underlie, the poor academic performance often seen after TBI. For example, Catroppa and Anderson [92] reported that children with TBI demonstrated impairments in memory functioning 2 years post-injury and their academic success was dependent on both the demands of the tasks they completed and the severity of their injury. These results suggest that, when minimal demands are placed on students with TBI, their impairments may not be apparent. However, when students are working within a busy classroom, full of noise and distraction, their capacity to complete tasks which tax higher-order cognitive skills (e.g. solving math problems in your head) may be reduced, and any TBI-related impairments are likely to be much more apparent. The nature and extent of impairment in other social function may also impact on the young person's academic capabilities. Along these lines, Yeates and Taylor [93] noted that poorer behavioral adjustment predicted both poorer classroom performance and an increased likelihood of educational intervention, suggesting that successful intervention in certain areas is likely to positively impact on academic functioning.

In a large-scale follow-up of survivors of severe TBI, Asikainen and colleagues [94] found that coma scores, duration of unconsciousness and traumatic amnesia, all traditional markers of injury severity, significantly predicted occupational outcome up to 20 years post-injury. This group [95] also noted that those who sustained their injuries earlier in life, coupled with poor educational attainment, were the least likely to be gainfully employed as adults. Although no neuropsychological test data were provided, it is likely that cognitive and behavioral impairments had a detrimental effect on academic achievement, followed by a knock-on effect to occupational success. This evidence suggests that leaving post-TBI impairments untreated or not treating them successfully using appropriate intervention strategies can have wide-reaching and long-term implications.

Novel, innovative intervention approaches

Recently a number of novel and innovative techniques have been utilized in the treatment of TBI-related impairments. For example, virtual reality (VR) environments have been developed to assist clinicians when treating impairments in general executive functions [96], memory [97], and social cognition [98]. VR environments have the advantage of permitting the presentation of numerous and varied problems or tasks which can be repeated until improvement or mastery is achieved. VR environments are often more ecologically valid and accessible than traditional rehabilitation methods. For example, using an image of the patient rather than an avatar reduces cybersickness by not requiring the use of head-mounted display units, and not isolating the patient from the real world, enabling the clinician to readily and easily intervene and provide feedback during the session. One of the promising areas of VR-based rehabilitation is prospective memory impairment. Preliminary studies demonstrate that VR-based prospective memory tasks consistently discriminate between patients with frontal lobe injury and controls, and provide evidence of their potential utility to improve these impairments [99]. Although there are clear benefits to using VR-based interventions, the costs associated with this technology make it unavailable to the vast majority of clinicians.

Another successful approach to intervention is the SARAH program. The program, which began in the 1970s, is run across eight hospitals in Brazil and is based on the philosophy that children with TBI should

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be treated as a whole rather than a collection of parts. In addition, as TBI often results in impairments in various areas of functioning, the SARAH program actively includes parents, family members and teachers in the recovery process. To date, this approach has proven successful in treating broad-spectrum cognitive impairments [100] and holds promise for the treatment of emotional and behavioral difficulties commonly observed after TBI. Although there is little that is inherently novel about the SARAH approach, the active involvement of both the patient and their support network (both immediate and extended) ensures that the skills acquired during the intervention will not be context-dependent and will provide the patient with the confidence and the skill set with which to competently navigate their environment.

Finally, web-based technology has, of late, been utilized in the treatment of social skills impairments post-TBI. Wade and colleagues [101, 102] used the internet to deliver a series of therapeutic training sessions, based on cognitive-behavioral principles, with improved post-injury adjustment and self-management skills as well as self-reported parental distress. Families involved in the intervention were provided with a home computer, and completed sessions from home. The training module was structured as a 14-session package consisting of eight core sessions, each addressing specific topics (e.g. Steps of problem solving, Communication) and six sessions focusing on stressors experienced by some but not all families. The modules were designed to encourage family members to be actively involved and include tips, video clips demonstrating specific skills, as well as exercises that provide opportunities to practice the skills learned in that session.

In sum, a variety of intervention options are available for the treatment of post-TBI impairments. As described above, intervention strategies administered directly by clinicians (including rehabilitation nurses, physical therapists, and neuropsychologists among others), administered indirectly to families and teachers, using face-to-face problem-solving strategies or advanced computer-based technologies have all proven useful to treat cognitive, emotional, social, and behavioral impairments in children, adolescents and adults with TBI. There are a number of factors that a clinician should consider prior to engaging a patient with TBI in intervention including: the capabilities of the patient, the fit between patient and intervention requirements, the practical demands of the intervention, the empirical evidence supporting the intervention, the competence of the clinician in delivering the intervention according to its principles, and the likelihood of successful completion. While RCTs have the potential to greatly inform about the efficacy of the intervention, the lessons learned from single-case studies provide valuable information on appropriate and available strategies especially in terms of the patients' and their families' response and level of engagement in the intervention.

Future directions

Despite significant advances in the study of childhood TBI, the consequences of brain injuries sustained early in development remain less clear than those of similar injuries in adults. Nonetheless, there now exists good evidence demonstrating that a child's brain is vulnerable to early trauma and that skills that have not developed or are emerging at the time of injury may be permanently impaired, suggesting that childhood TBI can impact on an individual's cognitive, behavioral, emotional and social functioning well into adulthood and, indeed, throughout the lifespan. As a result of the previously widespread and erroneous notion that children's brains were "plastic" and could recover well from injury through transfer of function to undamaged areas, the chronicity of childhood TBI deficits is often underappreciated. The distinct outcomes of childhood versus adult TBI further highlight the importance of considering these types of injuries separately and avoiding inferring knowledge from the adult domain when considering children's brain injuries.

Notwithstanding the increasing evidence base that children are particularly vulnerable to brain injuries and that the consequences of these have long-lasting impacts on survivors' functioning and quality of life, further studies are needed to specifically describe the extent and severity of such life-long deficits. Although there are significant methodological difficulties and time requirements related to longitudinal studies, more "very long-term" follow-up studies on the outcome of childhood TBI are required to improve our knowledge of the lasting implications of such injuries, not just into adulthood, but throughout the entire lifespan. In particular, little is known of the interaction between early brain injuries and the normal degenerative processes related to the aging brain.

Much of the intervention research conducted to date has focused on the cognitive domain. As a result,

C:/ITOOLS/WMS/CUP/498812/WORKINGFOLDER/DOD/9780521896221C22.3D 324 [315–328] 24.8.2009 4:20PM

specific outcomes in the areas of attention, memory, language and executive function are clearly described. More recently, however, the focus of scientific attention has shifted to emotional and social domains and preliminary reports suggest that social dysfunction following childhood TBI is common, persistent, and represents the most debilitating of all sequelae. Nevertheless, evidence for this is still limited and more research is needed before we have a clear picture of the social outcomes of TBI. Progress in this area is currently limited by the paucity of adequate measures for assessing social function, suggesting there is a pressing need to develop specific, validated, reliable and standardized measures of social skills, which can be used in both research and clinical contexts.

Similarly, rehabilitation of social and emotional problems following childhood TBI is constrained by the lack of data evaluating the efficacy of behavioral interventions. While randomized control trials have become the gold standard in appraising the worth of such treatments, consideration of case studies and efficacy studies can provide valuable information in this regard. There are currently some useful resources available to clinicians which can provide additional information and assist when making a decision about intervention options. For example, *PsychBite* (http://www.psychbite.com) is a website which presents independent reviews (conducted by trained volunteer reviewers) of published intervention studies which are focused specifically on TBI-related impairments. Although the scores awarded to a study do not necessarily reflect the overall utility of the intervention, the review process nonetheless provides some useful information about the study and its methodological strengths. With the increase in calls for more methodologically rigorous studies, large multi-center trials may be necessary and it is important that the structure and focus of these studies take into account important developmental issues.

It is also recommended that clinicians and therapists investigate interventions that have been developed to address areas of impairment in other clinical populations (e.g. cognitive functioning in patients with Alzheimer's disease or aggression in adolescents with conduct disorder) as these strategies may have direct applications in the treatment of post-TBI impairments. Finally, following on from the suggestion by Catroppa and Anderson [103] that future intervention studies targeting executive functions should use appropriate and valid measures, it is also recommended that technological advances be utilized to engage and motivate patients and their families to participate in interventions that provide them with realistic and age-appropriate challenges to best prepare them for the transition back to the home, school, or workplace.

References

1. Mitra B, Cameron P, Butt W. Population based study of pediatric head injury. *J Ped Child Health* 2007;**43**(3):154–59.
2. Goldstein, FC, Levin, HS. Epidemiology of pediatric closed head injury: incidence, clinical characteristics and risk factors. *J Learn Disabil* 1987;**20**(9):518–25.
3. Michaud LJ, Rivara FP, Grady MS, Reay DT. Predictors of survival and severe disability after severe brain injury in children. *Neurosurgery* 1992;**31**(2):254–64.
4. Anderson V, Catroppa C, Morse S, Haritou F, Rosenfeld J. Functional plasticity or vulnerability after early brain injury? *Pediatrics* 2005;**116**(6):1374–82.
5. Rivara JB, Jaffe KM, Fay GC, Polissar NL, Martin KM, Shurtleff HA, et al. Family functioning and injury severity as predictors of child functioning one year following traumatic brain injury. *Arch Phys Med Rehabil* 1993;**74**(10):1047–55.
6. Taylor HG, Drotar D, Wade S, Yeates K, Stancin T, Klein S. Recovery from traumatic brain injury in children: the importance of the family. In Broman SH, Michel ME, eds. *Traumatic Head Injury in Children*. New York: Oxford University Press; 1995: 188–218.
7. Asarnow RF, Satz P, Light R, Lewis R, Neumann E. Behavior problems and adaptive functioning in children with mild and severe closed head injury. *J Pediatr Psychol* 1991;**16**(5):543–55.
8. Holloway M, Bye A, Moran K. Non-accidental head injury in children. *Med J Aust* 1994;**160**(12):786–89.
9. Quattrocchi KB, Prasad, P, Willits, NH, Wagner FC. Quantification of midline shift as a predictor of poor outcome following head injury. *Surg Neurol* 1991;**35**(3):183–8.
10. Pang D. Pathophysiologic correlates of neurobehavioral syndromes following closed head injury. In Ylvisaker M, ed. *Head Injury Rehabilitation: Children and Adolescents*. London: Taylor & Francis; 1985: 3–70.
11. Yeates KO. Closed-head injury. In Yeates KO, Ris MD, Taylor HG, eds. *Pediatric Neuropsychology: Research, Theory, and Practice*. New York: Guilford Press; 2000: 92–116
12. Engberg A, Teesdale G. Psychosocial outcome following traumatic brain injury in adults: A long-term

C:/ITOOLS/WMS/CUP/498812/WORKINGFOLDER/DOD/9780521896221C22.3D 325 [315–328] 24.8.2009 4:20PM

population-based follow-up. *Brain Inj* 2004;**18**(6):533–45.

13. Hoofien D, Gilboa A, Vakil E, Donovick P. Traumatic brain injury (TBI) 10–20 years later: a comprehensive outcome study of psychiatric symptomatology, cognitive abilities and psychosocial functioning. *Brain Inj* 2001;**15**(3):189–209.
14. Hessen E, Anderson V, Nestvold K. Neuropsychological function 23 years after mild traumatic brain injury: a comparison of outcome after pediatric and adult head injuries. *Brain Inj* 2007;**21**(9):963–79.
15. McKinlay A, Dalrymple-Alford JC, Horwood LJ, Fergusson DM. Long term psychosocial outcomes after mild head injury in early childhood. *J Neurol Neurosurg Psychiatry* 2002;**73**(3):281–88.
16. Hessen E, Anderson V, Nestvold K. MMPI-2 profiles 23 years after paediatric mild traumatic brain injury. *Brain Inj* 2008;**22**(1):39–50.
17. Klonoff H, Clark C, Klonoff, PS. Long-term outcome of head injuries: a 23 year follow up study of children with head injuries. *J Neurol Neurosurg Psychiatry* 1993;**56**(4):410–15.
18. Jonsson CA, Horneman G, Emanuelson I. Neuropsychological progress during 14 years after severe traumatic brain injury in childhood and adolescence. *Brain Inj* 2004;**18**(9):921–34.
19. Nybo T, Sainio M, Muller K. Stability of vocational outcome in adulthood after moderate to severe preschool brain injury. *J Int Neuropsychol Soc* 2004;**10**(5):719–23.
20. Asikainen I, Nybo T, Müller K, Sarna S, Kaste M. Speed performance and long-term functional and vocational outcome in a group of young patients with moderate or severe traumatic brain injury. *Eur J Neurol* 1999;**6**(2):179–85.
21. Cattelani R, Lombardi F, Brianti R, Mazzucchi A. Traumatic brain injury in childhood: intellectual, behavioural and social outcome into adulthood. *Brain Inj* 1998;**12**(4):283–96.
22. Nybo T, Koskiniemi M. Cognitive indicators of vocational outcome after severe traumatic brain injury (TBI) in childhood. *Brain Inj* 1999;**13**(10):759–66.
23. Koskiniemi M, Kyykka T, Nybo T, Jarho L. Long-term outcome after severe brain injury in preschoolers is worse than expected. *Arch Pediatr Adolesc Med* 1995;**149**(3):249–54.
24. Yeates KO, Taylor HG, Drotar D, Wade SL, Klein S, Stancin T, et al. Pre-injury family environment as a determinant of recovery from traumatic brain injuries in school-age children. *J Int Neuropsychol Soc* 1997;**3**(6):617–30.
25. Hoofien D, Vakil E, Gilboa A, Donovick PJ, Barak O. Comparison of the predictive power of socio-economic variables, severity of injury and age on long-term outcome of traumatic brain injury: sample specific variables versus factors as predictors. *Brain Inj* 2002;**16**(1):9–27.
26. Yeates KO, Taylor HG, Wade SL, Drotar D, Stancin T, Minich N. A prospective study of short- and long-term neuropsychological outcomes after traumatic brain injury in children. *Neuropsychology* 2002;**16**(4):514–23.
27. van Heugten CM, Hendriksen J, Rasquin S, Dijcks B, Jaeken D, Vles JH. Long-term neuropsychological performance in a cohort of children and adolescents after severe paediatric traumatic brain injury. *Brain Inj* 2006;**20**(9):895–903.
28. Giza CC, Prins ML. Is being plastic fantastic? Mechanisms of altered plasticity after developmental traumatic brain injury. *Dev Neurosci* 2006;**28**(4–5):364–79.
29. Giza CC, Mink RB, Madikians A. Pediatric traumatic brain injury: not just little adults. *Curr Opin Crit Care* 2007;**13**(2):143–52.
30. Donders J, Warschausky S. Neurobehavioral outcomes after early versus late childhood traumatic brain injury. *J Head Trauma Rehabil* 2007;**22**(5):296–302.
31. Silver CH. Ecological validity of neuropsychological assessment in childhood traumatic brain injury. *J Head Trauma Rehabil* 2000;**15**(4):973–88.
32. Chaytor N, Temkin N, Machamer J, Dikmen S. The ecological validity of neuropsychological assessment and the role of depressive symptoms in moderate to severe traumatic brain injury. *J Int Neuropsychol Soc* 2007;**13**(3):377–85.
33. Sbordone RJ. Limitations of neuropsychological testing to predict the cognitive and behavioral functioning of persons with brain injury in real-world settings. *NeuroRehabilitation* 2001;**16**(4):199–201.
34. Wechsler, D. *The Wechsler Abbreviated Scale of Intelligence*. San Antonio, TX: The Psychological Corporation; 1999.
35. Robertson IH, Ward T, Ridgeway V, Nimmo-Smith I. *The Test of Everyday Attention*. Bury St. Edmunds: Thames Valley Test Company; 1994.
36. Delis DC, Kaplan E, Kramer JH. *Delis Kaplan Executive Function System (D-KEFS)*. San Antonio, TX: The Psychological Corporation; 2001.
37. Wechsler, D. *Wechsler Memory Scale-Third Edition: Administration and scoring manual*. San Antonio, TX: The Psychological Corporation; 1997.

C:/ITOOLS/WMS/CUP/498812/WORKINGFOLDER/DOD/9780521896221C22.3D 326 [315–328] 24.8.2009 4:20PM

38. Wechsler, D. *Wechsler Individual Achievement Test – Second Edition (WIAT-II)*. San Antonio, TX: The Psychological Corporation; 2002.
39. Delis D, Kramer J, Kaplan E, Ober B. *California Verbal Learning Test-Second Edition*. San Antonio, TX: The Psychological Corporation; 2000.
40. Rey A. *L'examen clinique en psychologie (Clinical tests in psychology)*. Paris, France: Presses Universitaires de France; 1964.
41. Conners CK, MHS Staff, eds. *Conners' Continuous Performance Test II: Computer Program for Windows Technical Guide and Software Manual*. North Tonwanda, NY: Mutli-Health Systems; 2000.
42. Gronwall D, Sampson H. *The Psychological Effects of Concussion*. Auckland, New Zealand: University Press/ Oxford University Press; 1974.
43. Rey A. L'examen psychologique dans les cas d'encephalopathie traumatique. *Arch Psychol* 1941;**28**:286–340.
44. Berg EA. A simple objective technique for measuring flexibility in thinking. *J Gen Psychol* 1948;**39**:15–22.
45. Stroop JR. Studies of interference in serial verbal reactions *J Exp Psychol* 1935;**18**:643–622.
46. Strauss E, Sherman E, Spreen O. *A Compendium of Neuropsychological Tests: Administration, Norms and Commentary*, 3rd edn. Oxford: Oxford University Press; 2006.
47. Ewing-Cobbs L, Prasad MR, Kramer L, Cox CS Jr, Baumgartner J, Fletcher S, et al. Late intellectual and academic outcomes following traumatic brain injury sustained during early childhood. *J Neurosurg* 2006;**105**(4 Suppl):287–96.
48. Koskiniemi M, Kyykka T, Nybo T, Jarho L. Long-term outcome after severe brain injury in preschoolers is worse than expected. *Arch Pediatr Adolesc Med* 1995;**149**(3):249–54.
49. Nybo T, Sainio M, Muller K. Middle age cognition and vocational outcome of childhood brain injury. *Acta Neurol Scand* 2005;**112**(5):338–42.
50. Lachapelle J, Bolduc-Teasdale J, Ptito A, McKerral M. Deficits in complex visual information processing after mild TBI: electrophysiological markers and vocational outcome prognosis. *Brain Inj* 2008;**22**(3):265–74.
51. Ownsworth T, McKenna K. Investigation of factors related to employment outcome following traumatic brain injury: a critical review and conceptual model. *Disabil Rehabil* 2004;**26**(13):765–83.
52. Johnstone B, Hexum CL, Ashkanazi G. Extent of cognitive decline in traumatic brain injury based on estimates of premorbid intelligence. *Brain Inj* 1995;**9**(4):377–84.
53. Guerin F, Kennepohl S, Leveille G, Dominique A, McKerral M. Vocational outcome indicators in atypically recovering mild TBI: a post-intervention study. *NeuroRehabilitation* 2006;**21**(4):295–303.
54. Mateer CA, Sira CS. Cognitive and emotional consequences of TBI: intervention strategies for vocational rehabilitation. *NeuroRehabilitation* 2006;**21**(4):315–26.
55. Shames J, Treger I, Ring H, Giaquinto S. Return to work following traumatic brain injury: trends and challenges. *Disabil Rehabil* 2007;**29**(17):1387–95.
56. Yeates KO, Swift E, Taylor HG, Wade SL, Drotar D, Stancin T, et al. Short- and long-term social outcomes following pediatric traumatic brain injury. *J Int Neuropsychol Soc* 2004;**10**(3):412–26.
57. Willer, BS, Ottenbacher, KJ, Coad ML. The Community Integration Questionnaire: a comparative examination. *Am J Phys Med Rehabil* 1994;**73**(2):103–111.
58. Tate R, Hodgkinson A, Veerabangsa A, Maggiotto S. Measuring psychosocial recovery after traumatic brain injury: Psychometric properties of a new scale. *J Head Trauma Rehabil* 1999;**14**(6):543–557.
59. Wilson BA, Alderman N, Burgess PW, Emslie H, Evans JJ. BADS: Behavioural Assessment of the Dysexecutive Syndrome. London, UK: Thames Valley Test Company; 1996.
60. Anson K, Ponsford J. Who benefits? Outcome following a coping skills group intervention for traumatically brain injured individuals. *Brain Inj* 2006;**20**(1):1–13.
61. Draper K, Ponsford J, Schonberger M. Psychosocial and emotional outcomes 10 years following traumatic brain injury. *J Head Trauma Rehabil* 2007;**22**(5):278–87.
62. Ponsford J, Draper K, Schonberger M. Functional outcome 10 years after traumatic brain injury: Its relationship with demographic, injury severity, and cognitive and emotional status. *J Int Neuropsychol Soc* 2008;**14**(2):233–42.
63. Bloom DR, Levin HS, Ewing-Cobbs L, Saunders AE, Song J, Fletcher JM, et al. Lifetime and novel psychiatric disorders after pediatric traumatic brain injury. *J Am Acad Child Adolesc Psychiatry* 2001;**40**(5):572–9.
64. Hibbard MR, Bogdany J, Uysal S, Kepler K, Silver JM, Gordon WA, et al. Axis II psychopathology in individuals with traumatic brain injury. *Brain Inj* 2000;**14**(1):45–61.
65. Hathaway S, McKinley J. *MMPI-2 Manual for Administration and Scoring*. Minneapolis, MN: University of Minnesota Press; 1989.
66. Teasell R, Bayona N, Marshall S, Cullen N, Bayley M, Chundamala J, et al. A systematic review of the

C:/ITOOLS/WMS/CUP/498812/WORKINGFOLDER/DOD/9780521896221C22.3D 327 [315–328] 24.8.2009 4:20PM

rehabilitation of moderate to severe acquired brain injuries. *Brain Inj* 2007;**21**(2):107–12.

67. Wilson BA, Emslie H, Quirk K, Evans J, Watson P. A randomized control trial to evaluate a paging system for people with traumatic brain injury. *Brain Inj* 2005;**19**(11):891–94.
68. Suzman KB, Morris RD, Morris MK, Milan MA. Cognitive-behavioral remediation of problem solving deficits in children with acquired brain injury. *J Behav Ther Exp Psychiatry* 1997;**28**(3):203–12.
69. Madsen Sjö N, Weidner S, Spellerberg S, Kihlgren M. Cognitive training in local settings: two methodological versions. *New Frontiers in Pediatric Traumatic Brain Injury*; 2007 Nov 8–10; San Diego, USA.
70. Ponsford J, Willmott C, Rothwell A, Cameron P, Ayton G, Nelms R, et al. Impact of early intervention on outcome after mild traumatic brain injury in children. *Pediatrics* 2001;**108**(6):1297–1303.
71. Kirkwood M, Dise-Lewis J, Wathen J, Brent A, Wilson P. Comparison of three early educational interventions following pediatric mild TBI. *New Frontiers in Pediatric Traumatic Brain Injury*; 2007 Nov 8–10; San Diego, USA.
72. Max JE, Roberts MA, Koele SL, Lindgren SD, Robin DA, Arndt S, et al. Cognitive outcome in children and adolescents following severe traumatic brain injury: influence of psychosocial, psychiatric, and injury-related variables. *J Int Neuropsychol Soc* 1999;**5**(1):58–68.
73. Ylvisaker M, Turkstra L, Coehlo C, Yorkston K, Kennedy M, Sohlberg MM, et al. Behavioral interventions for children and adults with behaviour diorders after TBI: a systematic review of the evidence. *Brain Inj* 2007;**21**(8):769–805.
74. Wade SL, Michaud L, Maines-Brown T. Putting the pieces together: preliminary efficacy of a family problem-solving intervention for children with traumatic brain injury. *J Head Trauma Rehabil* 2006;**21**(1):57–67.
75. Medd J, Tate RL. Evaluation of an anger management therapy program following acquired brain injury: a preliminary study. *Neuropsych Rehabil* 2000;**10**(2):185–201.
76. Feeney T, Ylvisaker M. Choice and routine: antecedent behavioral interventions for adolescents with severe traumatic brain injury. *J Head Trauma Rehabil* 1995;**10**(3):67–86.
77. Burke W, Weslowski M. Applied behavior analysis in head injury rehabilitation. *Rehabil Nurs* 1988;**13**(4):186–8.
78. Zencius A, Weslowski M, Burke W, McQuade D. Antecedent control in the treatment of brain injured clients. *Brain Inj* 1989;**3**(2):199–205.
79. O'Reilly MF, Green G, Braunling-McMorrow D. Self-administered written prompts to teach home accident prevention skills with brain injuries. *J Appl Behav Anal* 1990;**23**(4):431–46.
80. Kennedy CH. Manipulating antecedent conditions to alter the stimulus control of problem behavior. *J Appl Behav Anal* 1993;**27**(1):161–70.
81. Carnevale GJ. Natural-setting behaviour management for the individuals with traumatic brain injury: Results of a three year caregiver training program. *J Head Trauma Rehabil* 1996;**11**(1):27–38.
82. Aescheman SR, Imes C. Stress inoculation training for impulsive behaviors in adults with traumatic brain injury. *J Rational-Emotive Cogn Behav Ther* 1999;**17**(1):51–65.
83. Treadwell K, Page T. Functional analysis: identifying the environmental determinants of severe behavior disorders. *J Head Trauma Rehabil* 1996;**11**(1):62–74
84. Willis T, LaVigna G. The safe management of physical aggression using multi-element positive practices in community settings. *J Head Trauma Rehabil* 2003;**18**(1):75–87.
85. Bornhofen C, McDonald S. Treating deficits in emotion perception following traumatic brain injury. *Neuropsychol Rehabil* 2008;**18**(1):22–44.
86. Hornak J, Rolls ET, Wade D. Face and voice expression identification in patients with emotional and behavioural changes following ventral frontal lobe damage. *Neuropsychologia* 1996;**34**(4):247–61.
87. McDonald S. Putting communication disorders in context after traumatic brain injury. *Aphasiology* 2000;**14**(4):339–47.
88. McDonald S. Traumatic brain injury and social function: let's get social. *Brain Impair* 2003;**4**(1):36–47.
89. Trower P. Situational analysis of the components and processes of behaviour of socially skilled and unskilledpatients. *J Consult Clin Psychol* 1980;**48**(3):327–39.
90. Hux K, Marquardt J, Skinner S, Bond V. Special education services provided to students with and without parental reports of traumatic brain injury. *Brain Inj* 1999;**13**(6):447–55.
91. Sharp NL, Bye RA, Llewellyn GM, Cusick A. Fitting back in: adolescents returning to school after severe acquired brain injury. *Disabil Rehabil* 2006;**28**(12):767–78.
92. Catroppa C, Anderson V. Recovery in memory function, and its relationship to academic success at 24 months following pediatric TBI. *Child Neuropsychol* 2007;**13**(3):240–61.
93. Yeates KO, Taylor HG. Behavior problems in school and their educational correlates among children with

C:/ITOOLS/WMS/CUP/498812/WORKINGFOLDER/DOD/9780521896221C22.3D 328 [315–328] 24.8.2009 4:20PM

traumatic brain injury. *Exceptionality* 2006;**14**(3):141–54.

94. Asikainen I, Kaste M, Sarna S. Predicting late outcome for patients with traumatic brain injury referred to a rehabilitation programme: a study of 508 Finnish patients 5 years or more after injury. *Brain Inj* 1998;**12**(2):95–107.
95. Asikainen I, Kaste M, Sarna S. Patients with traumatic brain injury referred to a rehabilitation and re-employment programme: social and professional outcome for 508 Finnish patients 5 or more years after injury. *Brain Inj* 1996;**10**(12):883–99.
96. Elkind JS, Rubin E, Rosenthal S, Skoff B, Prather P. A simulated reality scenario compared with the computerized Wisconsin Card Sorting test: an analysis of preliminary results. *Cyberpsychol Behav* 2001;**4**(4):489–96.
97. Matheis RJ, Schultheis MT, Rizzo AA. Learning and memory in a virtual office environment. In Burdea G, Thalmann D, Lewis JA, eds. *Proceedings of the 2nd International Workshop in Virtual Rehabilitation*; 2003 Sep 21–22; Piscataway, NJ, USA.
98. Osborne K, Preston AM. Brain training: social cognition in a virtual reality setting. *New Frontiers in Pediatric Traumatic Brain Injury*; 2007 Nov 8–10; San Diego, USA.
99. Morris RG, Kotitsa M, Bramham J, Brooks B, Rose FD. Virtual reality investigation of strategy formation, rule breaking and prospective memory in patients with focal prefrontal neurosurgical lesions. In Sharkey P, Lányi CS, Standen P, eds. *Proceedings of the 4th International Conference on Disability, Virtual Reality & Associated Technologies*; 2002 Sep 18–21; Veszprém, Hungary.
100. Braga LW, Da Paz AC, Ylvisaker M. Direct clinician-delivered versus indirect family-supported rehabilitation of children with traumatic brain injury: a randomized controlled trial. *Brain Inj* 2005;**19**(10):819–31.
101. Wade SL, Carey J, Wolfe CR. The efficacy of an online cognitive-behavioral family intervention in improving child behaviour and social competence following pediatric brain injury. *Rehabil Psychol* 2006;**51**(3):179–89.
102. Wade SL, Carey J, Wolfe CR. An online family intervention to reduce parental distress following pediatric brain injury. *J Consult Clin Psychol* 2006;**74**(3):445–54.
103. Catroppa C, Anderson V. Planning, problem-solving and organizational abilities in children following traumatic brain injury: Intervention techniques. *Pediatr Rehabil* 2006;**9**(2):89–97.