**This is the authors' copy of the final manuscript.**

**To cite the published article:** J. Limond, A-L.R. Adlam & M. Cormack , The Clinical Neuropsychologist (2014): A Model for Pediatric Neurocognitive Interventions: Considering the Role of Development and Maturation in Rehabilitation Planning, The Clinical Neuropsychologist

**To link the published article:** http://dx.doi.org/10.1080/13854046.2013.873083

# A Model for Pediatric Neurocognitive Interventions: Considering the Role of Development and Maturation in Rehabilitation Planning

J. Limond[1,2], A-L., R. Adlam[3], M. Cormack[4]

[1] CoRaL Psychology Ltd, Centrum House, 38 Queen Street, Glasgow G1 3DX, UK

[2] Mental Health and Wellbeing, University of Glasgow, Gartnavel Royal Hospital, 1055 Great Western Road, Glasgow G12 0XH, UK

[3] Centre for Clinical Neuropsychology Research, School of Psychology, University of Exeter, Exeter, EX4 4QG, UK

[4] NHS Lanarkshire, LD CAMHS, 49 Airbles Road, Motherwell, ML1 2TJ

**Abbreviated Title:** A Pediatric Neurocognitive Interventions Model

**Abstract**

The need for post-acute neurorehabilitation after childhood acquired brain injury is increasingly recognized but recent reviews highlight the limited evidence-base and lack of a neuropsychological treatment model. Evidence from different fields was reviewed to inform the development of a pediatric neurocognitive interventions (PNI) model. The review included literature from child neuropsychology, adult neuropsychology, cognitive neuroscience, learning disabilities, education, and mental health. The resulting PNI model provides a systematic approach to delivering and evaluating appropriate care while minimizing the obstacles to successful outcomes. The model emphasizes the role of development and cognitive maturation in the planning of rehabilitation. Areas that represent significant gaps in our knowledge are discussed and future research directions are suggested based on predictions generated by the proposed model.

**Keywords:** children, brain injury, cognitive rehabilitation. **Abbreviations**: ABI: acquired brain injury; CABI: childhood acquired brain injury; PNI: pediatric neurocognitive interventions; TBI: traumatic brain injury.

The model presented here aims to provide the clinical and research communities with a systematic approach to delivering and evaluating pediatric neurocognitive interventions (PNI) while minimizing the obstacles to successful outcomes. For clinical utility, the model can guide clinical reasoning through very complex presentations; mapping the neurocognitive mechanisms that need to be addressed in any individual rehabilitation program and highlighting some of the systems and resources that need to be considered (or built up) when neurocognitive interventions are implemented. The severity of injury, premorbid development, and the complexity of the child's social context will determine the relative mix of higher order levels of neurocognitive intervention and psychosocial or basic skills training components. The model does not intend to dictate the specificity or sequence of interventions (i.e., interventions may not need to start at the most basic level and may target multiple levels). Instead, the model aims to provide the clinician and researcher with a framework to guide assessment and intervention. It is also hoped that the model will stimulate clinicians to look at links to other services that may support their rehabilitation objectives in wider settings. An additional aim of the model is to stimulate research to further develop an evidence base for interventions, by providing testable hypotheses for both group and single-case designs.

**Evidence For The Value Of Pediatric Neurocognitive Interventions**

Traumatic brain injury (TBI) is the leading cause of death and disability in childhood (Carli & Orliaguet, 2004) and in the UK it is estimated that every year 280 children per 100,000 require hospitalization for 24 hours or more following a TBI (Hawley, Ward, Long, Owen, & Magnay, 2003). Similar rates of injury occur in the USA (Faul, Xu, Waid, Coronado, & Dellinger, 2010) and Australia (Crowe, Babl, Anderson, & Catroppa, 2009). In addition, conditions such as brain tumours, stroke, and central nervous system infections can have significant neurocognitive sequelae and constitute acquired brain injuries (ABI; an umbrella term that includes traumatic brain injury). With advances in acute care, a majority of individuals survive ABI, however the long-term or life-long effects on social functioning, cognition, emotions, and behavior, mean that ABI remains the leading cause of disability (Fleminger & Ponsford, 2005). This is of particular concern for ABI occurring in childhood, where development can be compromised, existing difficulties exacerbated, and the potential for developing secondary learning and behavioral problems is increased (Ewing-Cobbs et al., 2004; Limond, Dorris, & McMillan, 2009). Families also report significant distress and burden when caring for a child who has survived an ABI, leading to an increased risk of mental health difficulties in parents and siblings, and marital breakdown (Rivara et al., 1996; Tomlin & Viehweg, 2003; Wade, Wolfe, Maines, Brown, & Pestian, 2005; Wade, Carey, & Wolfe, 2006; Wade et al., 2010).

Without appropriate neurocognitive rehabilitation, childhood ABI (CABI) can also lead to increased risk of substance misuse (McKinlay, Grace, Horwood, Fergusson, & MacFarlane, 2009), mental health difficulties (Max et al., 1998), unemployment, underemployment and criminal behavior in adulthood (Williams, Cordan, Mewse, Tonks, & Burgess, 2010). Thus, the long-term costs of CABI to the individual, their family and society as a whole, can be substantial (Anderson, Brown, Newitt, & Hoile, 2009). Despite this burden, reviews of the literature have highlighted the limited number of studies that guide the choice of treatments for different cognitive and psychosocial impairments (Catroppa & Anderson, 2009; Limond & Leeke, 2005; Laatsch et al., 2007; Slomine, 2009; Ross, Dorris, & McMillan, 2011; Diamond & Lee, 2011), and all emphasize the importance of developing effective models of PNI to ensure high quality health care outcomes.

**Pediatric Neurocognitive Interventions Within The Context Of Typical Cognitive Development**

It is apparent to clinicians working with children that adult models of intervention can be helpful to consider but some important adaptations will always need to be made (e.g., Wright & Limond, 2004). Within pediatric neuropsychology the most obvious element that is not addressed by adult approaches is that of on-going cognitive development. There is no single model of cognitive development that allows us to pinpoint at what age and in what order different cognitive processes reach maturity (e.g., Crone & Ridderinkhof, 2011). There is, however, increasing research evidence to support the interdependence of development in different cognitive systems (e.g., Goswami, 2008; Johnson, Halit, Grice, & Karmiloff-Smith, 2002; Karmiloff-Smith, 1998). This issue is highlighted by Spevack (2007) who states that "the various components of the brain are interconnected and organized into functional systems that operate in tandem, as well as independently. These systems change over the course of development, reflecting a process of continuous neural 'remodeling' that enables greater behavioral efficiency and complexity as maturation progresses (p8)". Bernstein (2010) also describes the need to consider a brain-context-development matrix to incorporate these multiple levels that contribute to the maturational process. Karmiloff-Smith and colleagues (e.g., Johnson et al., 2002; Karmiloff-Smith, 1998) hypothesize a neuroconstructivist approach to brain/cognitive development, in which functional specialization is considered to be highly context-sensitive and depends on interactions with other brain regions through feedback processes (Mechelli, Penny, Price, Gitelman, & Friston, 2002). Thus according to current models of typical development, the developing brain is dynamic and self-structuring due to multiple interactions at multiple levels, ranging from gene expression through to environmental experience.

Despite this, evidence from the neuroimaging and developmental literature suggests that cognitive development can occur in a predictable fashion. Neuroimaging studies show that the brain structures recruited to perform cognitive tasks change with age. For example, Scherf et al. (2006) found that adolescents and adults recruited the dorsolateral prefrontal cortex and parietal regions during a visuospatial working memory task, whereas younger children primarily recruited the caudate nucleaus and anterior insula. Changes in neural activation might therefore account for the performance changes shown throughout development (e.g., moving from simple storage to the processing of information). Consistent with this, developmental research has shown that although multiple strategies are available to children at every age, the most frequently used strategies change with age (e.g., Siegler, 1996). This change in strategy selection and efficiency is dependent on increases in cognitive capacity, a more elaborated knowledge base, and metacognitive competence (DeMarie, Miller, Ferron, & Cunningham, 2004).

We propose, therefore, that consistent with the predictable patterns of cognitive and strategy development, PNI models would benefit from considering a sequential approach to intervention. Furthermore, given that each child's 'goal' is to reach maturity, there is also a role for adult theories and models of cognitive function and organization. One adult model that also highlights the inter-dependence of cognitive skills is that of Shallice and Cooper (2011). They describe a 'cognitive computational engine' which comprises three basic aspects: i) semantic elements in thought, ii) short-term retention, buffers, priming and working memory, and iii) operations. Additional highly specific properties are then added on to this 'cognitive computational engine' such as supervisory system processes, episodic memory, thinking and consciousness. From a rehabilitation point of view, such models suggest that basic aspects of the 'engine' must be optimised to facilitate rehabilitation of higher-order specific processes such as the supervisory system. Or put another way, if an intervention for high-order skills is not effective, we should hypothesise that a more basic aspect of the 'engine' is impaired. Such models give us a potential scientific basis for prioritizing interventions where multiple impairments are presented.

An adult model such as Shallice and Cooper's (2011) can help us to consider the reliance of 'higher-order skills' on more fundamental processes, but we still need to bear in mind the cognitive developmental context. In adult rehabilitation, unimpaired skills that have already matured can be harnessed to support skills that have been impaired following brain injury. For example, in Shallice and Cooper's descriptions, semantic knowledge is seen as key for contributing to other processes. However, when working with children whose semantic knowledge base is still 'under construction', we also need to consider how to establish and maintain the growth of this semantic 'base' by supporting other inter-dependent processes such as phonological processing, working memory, and processing speed. For example, Fry and Hale (1996) found that 45% of the age-related increase in fluid intelligence was mediated by developmental change in processing speed and working memory. Furthermore, 71% of the maturation of working memory capacity was mediated by improvements in processing speed.

The aim of PNI is to rehabilitate impaired processes to a level as close to typical development as possible. A maturational or developmental perspective allows us to avoid programs or interventions that rely on skills that could not be expected to have developed yet. To this end, clinicians need models of PNI that can guide decisions about prioritization and timing of targeted interventions based on knowledge of how cognitive domains inter-relate, as well as how they develop. We refer to this as the cognitive-developmental context. A PNI model also needs to be cyclical, where the hierarchy is revisited as the child matures/develops. At this stage it is still unclear whether an intervention that is successful in early childhood will continue to have the same benefit at a later point in the child's developmental trajectory, i.e., are treatment gains maintained over time? Nor can we easily predict if a child's skills will plateau again when additional cognitive skills are normally expected to come on-line, i.e. if treatment gains are maintained, do the skills continue to develop in the context of other cognitive functions? These are important questions to be addressed with future research. However, for the clinician these unanswered questions indicate a need for regular follow-up to identify and address downstream issues not apparent until a later period of development, and to establish whether interventions need to be introduced or repeated.

Another important consideration is the matching of intervention strategy to developmental stage. The work of Björklund and colleagues (e.g., Björklund, Miller, Coyle, & Slawinski, 1997; Schwenke, Bjorklund, & Schneider, 2007) highlights the need to employ memory strategies sensitive to developmental limitations of strategy choice, implementation, and benefit. Looking at the typical development of memory in children they found that ability can vary as a result of both core memory skills and variation in the ability to deploy strategies that aid recall. Their research suggests that children can be taught effective strategies too early, resulting in a failure to benefit due to not knowing when to implement strategies despite having learned how to use them. It is important to acknowledge that different strategy deficiencies might be encountered at different developmental stages i.e. production deficiencies (not spontaneously using a known beneficial strategy) and utilization deficiencies (using a strategy spontaneously or after having been trained to do so, but not benefiting from its use). Bjorklund (2012) also describes Siegler's adaptive strategy choice model suggesting that multiple strategies exist within a child's repertoire at any one time, where practice and maturation allow more efficient strategies to be used more frequently. "…development *[of strategy use]* does not occur in a step like fashion but, rather, as a series of overlapping waves, with the pattern of those waves changing over time" (*op. cit.*, p 271).

The importance of developmental factors has also been increasingly recognized within the study of executive functions in children. Diamond (2013) proposes a model of executive function that describes core executive skills, working memory, inhibitory control and cognitive flexibility, which start emerging in children as young as two years. These core skills continue to mature throughout early to mid-childhood and contribute to the protracted development of higher-level executive functions - reasoning, problem-solving and planning. Research suggests that performance on tasks measuring core skills such as inhibitory control (e.g. Go/No-Go tasks) reaches adult-levels by the age of 12 years (Bedard et al., 2002), whereas performance on planning tasks (e.g. Tower of London) reaches maturity around the age of 21 years (Huizinga, Dolan, & van der Molen, 2006). All of these executive function skills are crucial to the use of strategies and interventions in children, and will be affected by age and individual developmental trajectories.

Within this context, issues around the heterogeneity of impairments following CABI also need to be considered. A child may fail to benefit from a memory strategy because of maturational limitations, as described above, but may also fail to benefit because of additional cognitive impairments over and above developmental needs. We know, for example, that slow information processing is a key component in restricting the strategic use of working memory (e.g., Case, 1995) and that attention deficits lead to limited elaboration and poor storage of information (e.g., O'Neill & Douglas, 1996) so a model of PNI needs to identify these potential obstacles via wide-range assessments and then consider that it may be most appropriate to work on developing information processing and attention before trying to introduce specific memory strategies. This has yet to be empirically tested, but will be crucial in shaping the development of PNI.

**Current Models of Pediatric Neurocognitive Intervention**

In light of the complexities described above, a number of models and frameworks have been developed to help guide the clinician and to some extent, the researcher, in PNI. The World Health Organization proposed the International Classification of Functioning, Disability, and Health (WHO-ICF, 2001), and more recently the International Classification of Functioning, Disability, and Health – Children and Youth (WHO-ICF-CY, 2007). These frameworks provide the clinician and researcher with a means to describe how the health condition (disorder/disease level) impacts on the body (impairments level), activities (activity limitations level) and participation (participation restrictions level). Within this framework, these levels interact with and are influenced by the environment and personal factors. Recent studies have expanded the ICF-CY to include factors such as development and quality of life (e.g., McDougall, Wright, & Rosenbaum, 2010; McDougall, Wright, Schmidt, Miller & Lowry, 2011).

This biopsychosocial/contextual model of function can be a helpful framework to guide clinical assessment and case conceptualization. For example, the 2001 WHO-ICF framework has been used to guide neuropsychological rehabilitation approaches for adults (e.g., Tate & Perdices, 2008; Wilson, Gracey, Evans, & Bateman, 2009b) and children (Ylvisaker, Hanks, & Johnson-Green, 2003). The ICF, however, does not provide a good account of how the various levels of function interact and influence each other, nor does it guide the clinician in their choice of priorities of when and where to intervene. From a research perspective, the ICF model does not make clear predictions about the potential mechanisms or underlying processes contributing to rehabilitation outcome, thus making it difficult to evaluate the mechanisms of change.

Approaches specifically addressing pediatric neuropsychology (e.g., Byard, Fine, & Reed, 2011; Wright & Limond, 2004) attempt to describe the variety of neurocognitive needs that require consideration when providing rehabilitation, but tend to focus on specific impairments (e.g., episodic memory) and do not provide a structured progression to guide a clinician's choice of where and when to intervene when multiple impairments are identified.

One pediatric model outside the neuropsychology corpus that has attempted to illustrate the notion of sequential steps in treatment is that of trauma-focused cognitive behavioural therapy (CBT). Trickey (2008) has depicted the psychological treatment of trauma as the highest stage in a hierarchy of intervention and support. His 'pyramid' has trauma work resting on a foundation of stabilization and family work, illustrating the need for initial work aiming to develop therapeutic resources. Together these foundations serve as a necessary basis for the patient to be able to benefit from complex therapy. While not a neuropsychological intervention, it demonstrates that complex interventions need multiple treatment components while also specifying the foundations required to manage treatment obstacles, so that those interventions provide the optimal benefit while avoiding harm.

In summary, some advances have been made in terms of models and frameworks to guide PNI, but further work is needed in this area to develop theory driven models that combine neurocognitive and psychosocial variables in a model that can be scientifically tested.

**A Model To Guide Comprehensive Pediatric Neurocognitive Interventions**

Here we present a hypothesis-testing approach to guide formulation and evaluation of each individual patient. The model aims to provide the clinician with a guide to aid decision-making regarding where and when to apply interventions within a developmental context. For example, if a child presents with impairment in prospective memory, but has behaviour problems and slow processing speed, is it best to start with a prospective memory intervention? The model presented here hypothesises that an intervention targeting prospective memory is likely to be most effective if lower level cognitive functions (e.g., working memory, processing speed) and psychosocial factors such as motivation, emotion, and behavior are relatively unimpaired. The model suggests that lower cost interventions such as behavior management can be applied first if such difficulties are present.

Research is still in its infancy and so far the literature indicates that many impairments do not seem to respond to interventions in the way traditional research would initially predict (e.g., Krasny-Pacini, Limond, Evans, & Chevignard,*in press*). We suggest that much of the individual variance in response to interventions found in research and clinical practice results from: i) background psychosocial noise; ii) individual differences across related neurocognitive domains; and/or iii) a failure to adequately take into account cognitive developmental context. Individual circumstances will therefore dictate which aspects of this model will require intervention in each case. This model is presented as a bottom-up approach which assumes that consideration of psychosocial foundations (e.g., behavior, emotion, family adjustment) is a pre-requisite to any neurocognitive intervention (see figure 1). A full discussion of the psychosocial sequelae of CABI is beyond the scope of this paper and therefore, is only briefly presented here.

INSERT Figure 1 – Pediatric Neurocognitive Interventions Model

**Psychosocial factors: social, emotional and behavioral foundations to neurocognitive interventions**

It is widely recognized that cognitive functioning is affected by numerous non-cognitive factors which can falsely create the appearance of, for example, executive function disorders (Diamond, 2013). The child's social and family environment will impact on the outcome and presentation of the impairment (e.g., Chapman & McKinnon, 2000) and is also likely to affect the impact of intervention strategies on the assessed problem (e.g., Ries, Potter, & Llorente, 2007). Many children have chaotic, unpredictable home environments where their basic needs are not reliably met by parents or caregivers. Moreover, these caregivers may lack the cognitive, emotional, and practical resources to learn and adapt new strategies and implement advice and recommendations.

In terms of intervention, it is important to determine if the child's psychosocial environment possesses requisite stability and resources to support rehabilitation goals, and provides the foundation on which effective PNI rests. The social, emotional and behavioral prerequisites to neurocognitive intervention need ongoing monitoring and management due to their potential role as obstacles to successful PNI. Key clinical areas to consider include: pragmatic factors and environmental adaptations; family function; challenging behavior; emotional competence (e.g., child's ability to recognize emotion, theory of mind); mental health of child and family; and motivational factors.

**Level A Interventions: Compensatory strategies cued/supported by others to develop semantic knowledge and support adaptive functioning**

Research is still in the early stages for interventions supporting cognitive difficulties following CABI. A variety of specific strategies have been developed to support impairments in several cognitive domains and there are a number of reviews of their efficacy (e.g., Limond & Leeke, 2005; Laatsch et al., 2007; Slomine & Loascio, 2009).

The most fundamental level of PNI involves assisted use of specific strategies such as errorless learning (e.g., Mueller, Palkovic & Maynard, 2007), elaborative encoding (e.g., Oberg & Turkstra, 1998), structuring processes (e.g., Franzen, Roberts, Schmidts, Verduyn, & Manshadi, 1996), or rehearsal strategies (e.g., Harris, 1996) to ensure the development of a secure knowledge base and advance compensatory aids (e.g., Wilson et al., 2009a) to improve adaptive functioning. These can rely on prompting or support from care-givers and may address cognitive impairments that are also being supported through environmental modifications and high levels of school and home support. Support workers and care-givers can prompt when strategies are needed and can keep the child on track whilst the strategy is used (Björklund, Miller, Coyle & Slawinski, 1997; Schwenk, Bjorklund & Schneider, 2007). These approaches are most likely to be used for young children learning something for the first time or for those with global developmental delay, specific learning difficulties, or semantic memory impairments. However, strategy selection will depend on the child's level of cognitive maturity and may even include complex strategies such as mind maps, essay templates, and mnemonics (e.g., Rankin & Hood, 2005). As children mature, or if they have specific strengths and weaknesses in other areas, they may progress to higher levels of the model. This level may be appropriately introduced at the same time as general environmental adaptations and psychosocial therapeutic work (the foundations for PNI, see above). Some aspects of supported strategy use may also be introduced for children who have challenging behavior or mental health difficulties that are being addressed as part of the psychosocial aspects of care, depending on the family's and child's priorities and the neuropsychological formulation.

**Level B Interventions: Maximizing core skills such as sustained and selective attention, working memory, inhibitory control, sequencing, and processing speed through remediation programs**

Sustained and selective attention, working memory, inhibitory control, sequencing skills (the ability to recognize and learn sequential patterns) and processing speed are particularly vulnerable in CABI and difficulties in these areas are likely to have profound effects on all aspects of a child's life. Impairments in working memory and the ability to sustain attention are likely to have an impact on the development of literacy and numeracy and will affect performance on all cognitive 'on-line' tasks (Baddeley, 2003; Daneman &

Carpenter, 1980; Engle, Tuholski, Laughlin, & Conway, 1999). Both attention and working memory difficulties are very likely to limit acquisition of new information and skills. In addition, clinicians frequently see these difficulties being misinterpreted by others, for example where children with poor attention or working memory are seen as intentionally failing to follow instructions. Remediation and compensation of these basic processes are proposed as the next layer of PNI. The model hypothesizes that these require consideration before further neurocognitive intervention is planned.

There is increasing evidence of the potential for improvement of skills in both attention (Galbiati et al., 2009) and working memory (Lohaugen et al., 2011) through the use of computerized remediation programs and individual training approaches for CABI (e.g., Van't Hooft, Andersson, Sejersen, Von Wednt, & Bartfai, 2005; Van't Hooft et al.,2007; Sjo, Spellerberg, Weidner, & Kihlgren, 2010). In terms of interventions for inhibitory control there is currently limited research within CABI (Feeney, 2010), however, there is promising evidence in the developmental literature (Diamond & Lee, 2011).

Impairments in sequencing and the ability to follow step-by-step processes can be significantly impaired in CABI, even when factoring out working memory load (Allen et al., 2010). Such impairments can be an obstacle to PNI by preventing successful use of compensatory intervention strategies. The PNI model hypothesises that improving sequencing skills can be instrumental in promoting successful and efficient strategy use in children, and may be one of the factors contributing to positive reports following computerized working memory training.

Impairments such as slowed processing speed can have similar impacts to the difficulties described above but also introduce a level of frustration in immediate social interactions and a high level of negative feedback for the individual concerned. Evidence to support improvements in processing speed are limited but there are some studies emerging for older adults (Willis et al., 2006), for children in foster care due to abuse or neglect (Mackey, Hill, Stone, & Bunge, 2011), and children following CABI (Oatman-Stanford, 2013).

Given the research literature outlined earlier, it is important to consider developmental factors when selecting appropriate skill training at this level. For example, if impairments are detected in both processing speed and working memory, it is predicted that interventions will be more effective if processing speed is targeted before engaging in working memory training, or indeed that improved processing speed might facilitate the development of working memory (Fry & Hale, 1996).

A deficit in any of the areas described above may reduce an individual's ability to learn or deploy compensatory strategies for higher level impairments (e.g., episodic memory impairment) and, therefore, this model hypotheses that maximizing and developing these skills as far as possible before considering more specific strategies will increase the long-term benefit of interventions targeting higher order cognitive impairments. This hypothesis remains the least well tested element of the PNI model and should be a current focus for research.

**Level C Interventions: Developing and supporting evaluative skills such as cognitive flexibility, metacognition, supervisory processes, self-regulation and reasoning skills through skills training programs**

It is increasingly recognized that cognitive flexibility and metacognitive skills (Butler et al., 2008; Ylvisaker & Feeney, 2002) are a critical component in the successful use of more specific strategies following CABI. Cognitive flexibility, although considered a 'core executive function skill', appears much later in development than working memory and inhibitory control (Diamond, 2013) but is crucial to being able to consider a variety of perspectives both interpersonally, and when addressing a novel task or problem. Metacognitive skills include insight/self-awareness, self-monitoring, and supervisory processes. All of these would be considered as contributing to executive function development and continue to mature throughout childhood into early adulthood (see Diamond, 2013 for a review).

Ylvisaker and Feeney (2002) highlight the importance of metacognitive skills in behavior and social function and recommend following a scaffolded[1] approach to ensure their emergence in CABI. Furthermore, there is some evidence for self-regulation interventions (self-monitoring, self-monitoring plus reinforcement, self-management, and self-reinforcement) in dysexecutive neurodevelopmental conditions such as attention deficit hyperactivity disorder (e.g., Reid, Trout, & Schartz, 2005).

The contribution of these types of skills to broader intervention programs is further demonstrated by Butler et al. (2008) and Butler and Copeland (2002) who developed a metacognitive program to be used alongside more traditional attention process training programs for children following treatment for cancer. Their results indicated positive outcomes in academic attainments and parental reports of everyday behavior, following the intervention (Butler et al., 2008).

Goal management training (Levine et al., 2007; 2000; involves teaching children to keep goals in mind using strategies such as mental review of a ‘mental blackboard’) and content-free cuing to prompt prospective memory (Fish, Wilson, & Manly, 2010) are emerging as areas of potential significance in adult ABI rehabilitation, and are now being

---

[1] “Scaffolding occurs when experts are sensitive to the abilities of a novice and respond contingently to the novice’s responses in a learning situation so that the novice gradually increases his or her understanding of a problem” Bjorklund, 2012; p84

explored in CABI (Krasny-Pacini et al., *in press*; Rous, Adams, Fish, Manly & Adlam, 2012). In addition, there is also some recent evidence to suggest that reasoning skills in children in foster care can be improved and generalized through the use of a relatively brief intervention (Mackey et al., 2011).

It is argued in this model that metacognitive skills are required if the aim is for children to independently apply the right strategies at the right time, and that developing these skills is an important pre-requisite to teaching complex strategies.

**Level D Interventions: Independent Strategy Use for Specific and Enduring Cognitive Impairments**

Teaching the independent use of task specific strategies is the highest level of intervention in this model. Examples include mnemonic strategies to support episodic or semantic learning, or strategies to enhance comprehension or creative writing. Level D strategies would be taught and scaffolded with the objective of independent use (e.g., Ylvisaker & Feeney, 2002), but may have been previously introduced at Level A, at which level they needed to be fully supported by others. Strategies can target any cognitive impairment, for example, visual processing difficulties, episodic memory deficits, language disorders such as word finding, comprehension or social pragmatic language impairments. In addition, aspects of attention and executive function that have not been fully developed despite intervention at levels C and D can be further supported at this level. For example, individuals who have successfully completed an attention training program may still need to use strategies to help in very busy or distracting environments. However, to utilise this level of intervention the child would have to apply intact metacognitive skills or those learnt at level C. Metacognitive skills are required because effective independent strategy use involves knowing when and where to apply an appropriately selected strategy. As described earlier the strategies taught need to be developmentally appropriate and, therefore, optimal strategy choice can change with age. Given the developmental framework, a very young child or a child with comorbid learning disabilities may not necessarily be expected to reach these higher levels of the model.

**Applying Multi-Level Interventions in the Context of the Pediatric Neurocognitive Interventions Model**

The model presented here does not preclude the use of multi-level neuropsychological interventions, which target more than one neurocognitive function (e.g., Level B, attention and Level C, metacognition). Instead the model predicts that for a multi-level intervention to be effective, it should target the lower-level processes (e.g., attention) and higher-level strategy (e.g., metacognition) sequentially. Two examples of effective multi-level interventions include the web-based Teen Online Problem-Solving intervention (Wade et al., 2005; 2006) and the Amsterdam Memory and Attention Training – for Children (van't Hooft et al., 2005; 2007; Sjo et al., 2010). Interestingly, both of these examples use a module-based approach, with the lower level process-based training occurring earlier in the programs than the higher-level strategy-based elements of training. This sequential application of modules is consistent with the theoretical underpinnings of the PNI model presented here.

**Problem Identification and Measurement in the Context of Pediatric Neurocognitive Interventions Model**

The model proposed here aims to guide assessment and intervention. For example, for a child with memory problems, is the memory deficit 'mild' or 'severe'; temporal or frontal in origin; co-morbid with attentional or other cognitive deficits; co-morbid with awareness deficits, adjustment or other emotional difficulties? Assessment and treatment approaches need to take account of the child's ability to understand their situation and engage with professionals and caregivers, and the team around the child will need to be sensitive to changes in the individual's identity and acceptance of the treatment options. Besides neuropsychological, behavioral, and emotional elements, PNI assessment requires significant focus on the developmental context. The assessment needs to determine at what point in the individual's development the problem has arisen and how this might affect the presentation and subsequent progression of the problem, and the likely response to intervention. Furthermore, given the dynamic developmental context, it is recommended that assessment is conducted at regular intervals to monitor developmental trajectory and to evaluate whether new interventions need to be applied or previous interventions need to be reinstated (see Figure 2).

INSERT Figure 2 – Using the PNI Model within the Context of Children's Recovery and Long-term Development

**Future Research Priorities**

The model presented here is based on our current theoretical knowledge and there are significant gaps in the literature. Furthermore, the model generates hypotheses regarding the sequence of interventions in relation to individual variables (e.g., what works for whom?). A number of research questions can therefore be generated to test the assumptions of the PNI model. Broad areas that might be prioritised for investigation include: Is it essential to target variables in the hierarchical sequence proposed, and are there any exceptions to this sequence? What are the mechanisms of change when multiple interventions are successful e.g., do improvements in processing speed enhance gains made in working memory training? How does age influence treatment gains at different levels of intervention?

Given the multiple interacting components that need to be addressed following CABI, PNI is by definition a complex intervention. The use of single-case research designs can be particularly helpful in evaluating complex interventions (e.g., Perdices & Tate, 2009; Tate et al., 2013). Dynamic assessment subsequent to a full neuropsychological evaluation, where a child's response to an intervention is assessed (Haywood & Lidz, 2007) can provide a useful evaluation of strategies that may or may not be helpful. Using this assessment approach will then enable the interventions identified as most likely to be of benefit to be evaluated in a pre- and post- goal outcome evaluation (e.g., Wilson et al., 2009b). A multiple baseline approach is also recommended where different strategies are predicted to affect different goals, allowing some evaluation of the specificity and generalizability of different interventions, as well as some precision to determine the mechanism of change.

In terms of conducting larger evaluative research, it is recommended (e.g., Medical Research Council 2000; 2008) that research is conducted in phases including: a feasibility/piloting phase (e.g., testing procedures, estimating recruitment /retention, determining sample size) and an evaluation phase (e.g., assessing effectiveness; understanding change process; assessing cost-effectiveness). Both of these phases can feedback into a development phase (e.g., identifying the evidence base; identifying/developing theory; modeling process and outcomes), leading to an implementation phase (e.g., dissemination; surveillance and monitoring; long term follow-up).

## Conclusions

This article described and presented a Pediatric Neurocognitive Interventions model to guide clinical practice and future research. The model was developed within the context of current evidence and literature from the fields of child neuropsychology, adult neuropsychology, cognitive neuroscience, learning disabilities, education, and mental health. As a result, the model emphasizes the role of development and cognitive maturation in the planning of rehabilitation. The model predicts that interventions will be most effective if they are organized according to the developmental needs of the child and family (e.g., providing psychosocial interventions before and alongside neurocognitive interventions). It is recommended that the model is systematically tested using both single-case and group-based research methodologies.

**Correspondence to**

Jenny Limond, CoRaL Psychology Ltd, 38 Queen Street, Glasgow G1 3DX

jenny@coralpsychology.co.uk

**Acknowledgements**

We would like to thank the reviewers and Professor Shari Wade for their invaluable comments on this manuscript.

**References:**

Adlam, A-L.R., Vizor, A., Gracey, F., Prince, L., & Humphrey, A. (2011).Considering the contextual factors in neuropsychological interventions following acquired brain injury occurring in childhood: a single case study. *Brain Impairment,12* (S).

Allen, D.N., Leany, B.D., Thaler, N.S., Cross, C., Sutton, G.P., & Mayfield, J. (2010). Memory and attention profiles in pediatric traumatic brain injury. *Archives in Clinical Neuropsychology, 25(7),* 618-33.

Anderson, V., Brown, S., Newitt, H., & Hoile, H. (2009). Educational, Vocational, Psychosocial, and Quality-of-Life Outcomes for Adult Survivors of Childhood Traumatic Brain Injury. *Journal of Head Trauma Rehabilitation, 24*(5), 303-312.

Baddeley, A. (2003). Working memory and language: An overview. *Journal of Communication Disorders, 36*, 189–208.

Bedard, A.C., Nichols, S., Barbosa, J.A., Schachar, R., Logan, G.D., & Tannock, R. (2002). The development of selective inhibitory control across the life span. *Developmental Neuropsychology, 21(1),* 93-111.

Bernstein, J.H. (2010). Developmental models in pediatric neuropsychology. In J. Donders & S.J. Hunter (Eds*), Principles and practice of lifespan developmental neuropsychology* (pp. 17-40). Cambridge: Cambridge University Press.

Best, J.R. (2010). Effects of physical activity on children's executive function: Contributions of experimental research on aerobic exercise. *Developmental Review, 30*, 331-351.

Bjorklund, D.F. (2012). *Children's thinking: cognitive development and individual differences* (5th ed). Wadsworth: International Edition.

Bjorklund, D.F., Miller, P.H., Coyle,T.R., & Slawinski, J.L. (1997). Instructing children to use memory strategies: Evidence of utilization deficiencies in emory training studies. *Developmental Review*, 17, 411-442.

Butler, R.W., Copeland, D.R., Fairclough, D.L., Mulhern, R.K., Katz, E.R., Kazak, A.E., Nohl, R.B., Patel, S.K. & Sahler, O.J.Z. (2008). A multicenter, randomized clinical trial of a cognitive remediation program for childhood survivors of a pediatric malignancy. *Journal of Consulting and Clinical Psychology, 76*(3), 367-378.

Butler, R.W., & Copeland, D.R. (2002). Attentional processes and their remediation in children treated for cancer: A literature review and the development of a therapeutic approach. *Journal of the International Neuropsychological Society 8*(1), 115-124.

Byard, K., Fine, H., & Reed, J. (2011). Taking a developmental and systemic perspective on neuropsychological rehabilitation with children with brain injury and their families. *Clinical Child Psychology and Psychiatry, 16*(2), 165-184.

Carli P, Orliaguet G. (2004). Severe traumatic brain injury in children. *Lancet, 363(9409), 584-585.*

Case, R. (1995). Capacity-based explanations of working memory growth: A brief history and reevaluation. In: F.E. Weinert and W. Schneider (Eds.), *Memory performance and competencies: Issues in growth and development.* Hillsdale, NJ: Lawrence Erlbaum Associates.

Catroppa, C., & Anderson, V. (2009). Traumatic brain injury in childhood: rehabilitation considerations. *Developmental Rehabilitation, 12,* 53-61.

Chapman, S.B. & McKinnon, L. (2000). Discussion of developmental plasticity: Factors affecting cognitive outcome after paediatric traumatic brain injury. *Journal of Communication Disorders, 33,* 333–344.

Crone, E.A., & Ridderinkhof, K.R. (2011). The developing brain: From theory to neuroimaging and back. *Developmental Cognitive Neuroscience, 1,* 101-109.

Crowe, L., Babl, F., Anderson, V., Catroppa, C., (2009). The epidemiology of paediatric head injuries: data from a referral centre in Victoria, Australia. *Journal of Paediatric Child Health, 46,* 346–350.

Daneman, M., & Carpenter, P. A. (1980). Individual differences in working memory and reading. *Journal of Verbal Learning & Verbal Behaviour, 19*, 450–466. doi:10.1016/S0022- 5371(80)90312-6

DeMarie, D., Miller, P.H., Ferron, J., & Cunningham, W.R. (2004). Path analysis tests of theoretical models of children's memory performance. *Journal of Cognition & Development, 5*, 461-492.

Diamond, A. (2012). Executive functions. *Annual Review of Psychology, 64,* 19.1-19.34. doi: 10.1146/annurev-psych-113011-143750

Diamond, A. & Lee, K. (2011). Interventions shown to aid executive function development in children 4 to 12 years old. *Science, 333,* 959-964.

Engle, R., Tuholski, S., Laughlin, J., & Conway, A. (1999). Working memory, short-term memory, and general fluid intelligence: A latent-variable approach. *Journal of Experimental Psychology: General, 128,* 309–331. doi:10.1037/0096-3445.128.3.309

Ewing-Cobbs, L., Barnes, M., Fletcher, J.M., Levin, H.S., Swank, P.R., & Song, J. (2004). Modelling of Longitudinal Academic Achievement Scores After Paediatric Traumatic Brain Injury. *Developmental Neuropsychology, 25*(1-2), 107-133.

Faul, M., Xu, L., Wald, M.M., Coronado, V., Dellinger, A.M. (2010). Traumatic brain injury in the United States: national estimates of prevalence and incidence, 2002–2006. *Injury Prevention,* 16, A268.

Feeney, T. (2010). Structured Flexibility: The Use of Context-Sensitive Self-regulatory Scripts to Support Young Persons with Acquired Brain Injury and Behavioral Difficulties. *Journal of Head Trauma Rehabilitation, 25 (6),* 416–425. doi: 10.1097/HTR.0b013e3181fbc0a2

Fish, J., Wilson, B.A., & Manly, T. (2010). The assessment and rehabilitation of prospective memory problems in people with neurological disorders: A review. *Neuropsychological Rehabilitation, 20*(2), 161-179.

Fleminger, S., & Ponsford, J. (2005). Long term outcome after traumatic brain injury. *British Medical Journal, 331*, 1419-20.

Franzen, K.M., Roberts, M.A., Schmidts, D., Verduyn,W., & Manshadi, F. (1996). Cognitive remediation in pediatric traumatic brain injury. *Child Neuropsychology, 2*, 176–184.

Fry, A.F., & Hale, S. (1996). Processing speed, working memory, and fluid intelligence: Evidence for a developmental cascade. *Psychological Science, 7(4*), 237-241.

Galbiati, S., Recla, M., Pastore, V., Liscio, M., Bardon, A., Castelli, E., & Strazzer, S. (2009). Attention remediation following traumatic brain injury in childhood and adolescence. *Neuropsychology, 23*(1), 40-49.

Goswami, U. (2008). *Cognitive Development: The learning brain*. Hove, New York: Psychology Press.

Harris, J.R. (1996). Verbal rehearsal and memory in children with closed head injury: A quantitative and qualitative analysis. *Journal of Communication Disorders, 29*, 79–93.

Hawley, C.A., Ward, A.B., Long, J., Owen, D.W., & Magnay, A.R. (2003). Prevalence of traumatic brain injury amongst children admitted to hospital in one health district: A population based study. *Injury 34*, 256–260.

Haywood, H.C., & Lidz, C.S. (2007). *Dynamic Assessment in Practice – Clinical and Educational Applications.* Cambridge: Cambridge University Press

Holmes, J., Gathercole, S.E., & Dunning, D.L. (2009). Adaptive training leads to sustained enhancement of poor working memory in children. *Developmental Science, 12*(4), F9-F15.

Huizinga, M., Dolan, C.V., & van der Molen, M.W. (2006). Age-related change in executive function: Developmental trends and latent variable analysis. *Neuropsychologia, 44,* 2017-2036.

Johnson, M. H., Halit, H., Grice, S. J., & Karmiloff-Smith, A. (2002). Neuroimaging of typical and atypical development: A perspective from multiple levels of analysis. *Development and Psychopathology, 14* (3), 521-536.Karmiloff-Smith, A. (1998) Development itself is the key to understanding developmental disorders. *Trends in Cognitive Sciences, 2(10*), 389-398.

Kurowski, B., Martin, L.J., & Wade, S.L. (2012). Genetics and outcomes after traumatic brain injury (TBI): What do we know about pediatric TBI? *Journal of Paediatric Rehabilitation Medicine, 5* (3), 217-31.

Krasny-Pacini, A., Limond, J., Evans, J., & Chevignard, M. (*in press*). Context-sensitive goal management training for everyday executive dysfunction in children after severe traumatic brain injury. *Journal of Head Trauma and Rehabilitation*.

Kraus J.F., Rock A., & Hemyari P. (1990). Brain injuries among infants,children, adolescents and young adults. *American Journal of Disability in Childhood, 144*, 684–691.

Laatsch, L., Harrington, D., Hotz, G., Marcantuono, J., Mozzoni, M.P., Walsh, V. & Hersey, K.P. (2007). An evidence-based review of cognitive and behavioural rehabilitation treatment studies in children with acquired brain injury. *Journal of Head Trauma Rehabilitation, 22*(4), 248-256.

Levine, B., Stuss, D.T., Winocur, G., Binns, M.A., Fahy, L., Mandic, M., Bridges, K. &Robertson, I.H. (2007). Cognitive rehabilitation in the elderly: Effects on strategic behavior in relation to goal management. *Journal of the International Neuropsychological Society, 13*(1), 143-152.

Levine, B., Robertson, I.H., Clare, L, Carter, G., Hong, J., Wilson, B.A., Duncan, J &Stuss, D.T. (2000). Rehabilitation of executive functioning: An experimental–clinical validation of Goal Management Training. *Journal of the International Neuropsychological Society, 6*(3), 299-312.

Limond, J., Dorris, L., & McMillan, T.M. (2009). Quality of life in children with acquired brain injury: Parent perspectives 1–5 years after injury. *Brain Injury, 23*(7–8), 617–622.

Limond, J. & Leeke, R. (2005). Practitioner review: Cognitive rehabilitation for children with acquired brain injury. *Journal of Child Psychology and Psychiatry, 46*(4), 339-352.

Lohaugen, G.C., Antonsen, I., Haberg, A., Gramstad, A., Vik, T., Brubakk, A.M., & Skranes, J. (2011). Computerised working memory training improves function in adolescents born at extremely low birth weight. *Journal of Paediatrics, 158*(4), 555-561.

Lundqvist, A., Grundström, K., Samuelsson K., & Rönnberg J. (2010). Computerized training of working memory in a group of patients suffering from acquired brain injury. *Brain Injury, 24*(10), 1173-83.

Mackey,A.P., Hill, S.S., Stone, S.I. & Bunge, S.A. (2011). Differential effects of reasoning and speed training in children. *Developmental Science , 14* (3), 582-590.

Max, J. E., Koele, S.L.. Smith, W. L., Sato, Y., Lindgren, S. D., Robin, D.A., Arndt, S. (1998). Psychiatric disorders in children and adolescents after severe traumatic brain injury: A controlled study. *Journal of the American Academy of Child & Adolescent Psychiatry, 37* (8), 832-840. doi: 10.1097/00004583-199808000-00013

Max, J.E., Keatley, E., Wilde, E.A., Bigler, E.D., Schachar, R.J., Saunders, A.E., Ewing-Cobbs, L., Chapman, S.B., Dennis, M., Yang, T.T., & Levin, H.S. (2012). Depression in children and adolescents in the first six months after traumatic brain injury. *International Journal of Developmental Neuroscience, 30*, 239-245.

McDougall, J., Wright, V., & Rosenbaum, P. (2010). The ICF model of functioning and disability: Incorporating quality of life and human development. *Developmental Neurorehabilitation, 13*(3), 204-211.

McDougall, J., Wright, V., Schmidt, J., Miller, L., & Lowry, K. (2011). Applying the ICF framework to study changes in quality-of-life for youth with chronic conditions. *Developmental Neurorehabilitation, 14*(1), 41-53.

McKinlay, A., Grace, R., Horwood, J., Fergusson, D., & MacFarlane, M. (2009). Adolescent psychiatric symptoms following preschool childhood mild traumatic brain injury: evidence from a birth cohort. *The Journal of head trauma rehabilitation, 24*(3), 221-227.

Mechelli, A., Penny, W. D., Price, C. J., Gitelman, D. R., & Friston, K. J. (2002). Effective Connectivity and Intersubject Variability: Using a Multisubject Network to Test Differences and Commonalities. *NeuroImage, 17*(3), 1459-1469. doi:10.1006/nimg.2002.1231

Medical Research Council. (2008). *Developing and Evaluating Complex Interventions: New guidance.* London: MRC.

Mueller, M.M., Palkovic, C.M., & Maynard, C.S. (2007). Errorless learning: Review and practical application for teaching children with pervasive developmental disorders. *Psychology in the Schools, 44* (7), 691-700.

Oatman-Stanford, D. (2013). *Cognitive speed training for children who have survived an acquired brain injury: A feasibility and acceptability study* (Master's Thesis). University of Edinburgh, MSc Human Cognitive Neuropsychology.

Oberg, L., & Turkustra, L.S. (1998). Use of elaborative encoding to facilitate verbal learning after adolescent traumatic brain injury. *Journal of Head Trauma Rehabilitation, 13*, 44–62.

O'Neill, M.E., & Douglas, V.I. (1996). Rehearsal Strategies and Recall Performance in Boys With and Without Attention Deficit Hyperactivity Disorder. *Journal of Paediatric Psychology,* 21 (1), 73-88.

Perdices, M., & Tate, R. (2009) Single-subject designs as a tool for evidence-based clinical practice: Are they unrecognised and undervalued? *Neuropsychological Rehabilitation, 19*(6), 904-927.

Rankin, P.M. & Hood, J. (2005). Designing clinical interventions for children with specific memory disorders. *Paediatric Rehabilitation, 8* (4), 283-297.

Reid, R., Trout, A.L., & Schartz, M. (2005). Self-Regulation Interventions for Children with Attention Deficit/Hyperactivity Disorder. *Exceptional Children 71*(4), 361-377.

Reis, J.K., Potter, B.S., & Llorente, A.M. (2007). Multicultural aspects of pediatric neuropsychological intervention and rehabilitation. In S.J. Hunter and J. Donders (Eds.), *Pediatric Neuropsychological Intervention: A critical review of science and practice*. Cambridge: Cambridge University Press

Rivara, J.B., Jaffe, K.M., Polissar, N.L., Fay, G.C., Liao, S., & Martin, K.M. (1996). Predictors of family functioning and change 3 years after traumatic brain injury in children. *Archives of Physical Medicine and Rehabilitation, 77*(8), 754-764.

Ross, K.A., Dorris, L. & McMillan, T. (2011). A systematic review of psychological interventions to alleviate cognitive and psychosocial problems in children with acquired brain injury. *Developmental Medicine and Child Neurology, 53*(8), 692-701.

Ross, K.A., Dorris, L., & McMillan (2011). A systematic review of psychological interventions to alleviate cognitive and psychosocial problems in children with acquired brain injury. *Developmental Medicine & Child Neurology, 53,* 692–701.

Rous, R., Adams, M., Fish, J., Manly, T., & Adlam, A. (2012). Prospective memory intervention for adolescents with acquired brain injury: Developmental and psychosocial factors affecting outcomes. *Brain Impairment*, 13, 147-148.

Scherf, K.S., Sweeney, J.A., et al. (2006). Brain basis of developmental change in visusospatial working memory. *Journal of Cognitive Neuroscience, 18,* 1045–1058.

Schwenck, C., Bjorklund, D.F., & Schneider, W. (2007). Factors influencing the incidence of utilization deficiencies and other patterns of recall/strategy-use relations in a strategic memory task. *Child Development, 78*(6), 1771-1787.

Shallice, T., & Cooper, R.P. (2011). *The Organisation of Mind.* Oxford, England: University Press.

Siegler, R.S. (1996). *Emerging minds: The process of change in children's thinking*. New York: Oxford University Press.

Sjo, N.M., Spellerberg, S., Weidner, S., & Kihlgren, M. (2010). Training of attention and memory deficits in children with acquired brain injury. *Acta Paediatrica, 99,* 230-236.

Slomine, B. & Loascio (2009). Cognitive rehabilitation for children with acquired brain injury. *Developmental Disabilities Research Reviews, 15,* 133-143.

Spevack, T. (2007). A developmental approach to pediatric neuropsychological intervention. *Pediatric neuropsychological intervention*, 6-29.

Tate, R., & Perdices, M. (2008). Applying the International Classification of Functioning, Disability and Health (ICF) to Clinical Practice and Research in Acquired Brain Impairment. *Brain Impairment, 9*(2), 282-292.

Tate, R.L., Perdices, M., Rosenkoetter, U., Wakim, D., Godbee, K., Togher, L., McDonald, S. (2013). Revision of a method quality rating scale for single-case experiemental designs and n-of-1 trials: The 15-item Risk of Bias in N-of-1 Trials (RoBiNT) Scale. *Neuropsychological Rehabilitation, 23(5),* 619-638.

Tomlin, A.M. & Viehweg, S.A. (2003) Infant Mental Health: Making a Difference. *Professional Psychology: Research and Practice*, *34*(6), 617-625.

Trickey, D. (2008). Experiencing refugee status after previous trauma. In: P.L. Appleton (Ed.), *Children's Anxiety – A Contextual Approach.* Hove, New York: Routledge.

Van't Hooft, I., Andersson, K., Bergman, B., Sejersen, T., von Wendt, L. & Bartfai, A. (2007). Sustained favourable effects of cognitive training in children with acquired brain injuries. *NeuroRehabilitation 22*, 109-116.

Van't Hooft, I., Andersson, K., Sejersen, T., von Wednt, L. & Bartafai, A. (2005). Beneficial effects from a cognitive training programme on children with acquired brain injuries demonstrated in a controlled study. *Brain Injury, 7*, 511-518.

Wade, S.L., Gerry Taylor, H., Yeates, K.O., Drotar, D., Stancin, T., Minich, N.M., Schluchter, M. (2006). Long-term parental and family adaptation following pediatric brain injury. *Journal of Pediatric Psychology, 31* (10), 1072-83.

Wade, S.L., Carey, J., & Wolfe, C.R. (2006). An online family intervention to reduce parental distress following pediatric brain injury. *Journal of Consulting and Clinical Psychology, 74*(3), 445-454.

Wade, S.L., Walz, N.C., Cassedy, A., Taylor, H.G., Stancin, T., & Yeates, K.O. (2010). Caregiver functioning following early childhood TBI: do moms and dads respond differently? *NeuroRehabilitation*, *27*(1), 63-72.

Wade, S.L., Wolfe, C., Maines Brown, T., & Pestian, J.P. (2005). Putting the Pieces Together: Preliminary Efficacy of a Web-Based Family Intervention for Children with Traumatic Brain Injury. *Journal of Paediatric Psychology 30(5), 437-442.*

Williams, W. H., Cordan, G., Mewse, A. J., Tonks, J., & Burgess, C. N. W. (2010). Self-reported traumatic brain injury in male young offenders: A risk factor for re-offending, poor mental health and violence? *Neuropsychological Rehabilitation, 20*(6), 801-812.

Willis, S.L., Tennstedt, S.L., Marsiske, M., Ball, K., Elias, J., Koepke, K.M., Morris, J.N., Rebok, G.W., Unverzagt, F.W., Stoddard, A.M. & Wright, E. (2006). Long-term Effects of Cognitive Training on Everyday Functional Outcomes in Older Adults. *Journal of the American Medical Association, 296* (23), 2805-2814.

Wilson, B.A., Emslie, H., Evans, J.J., Quirk, K., Watson, P., & Fish, J. (2009a). The NeuroPage system for children and adolescents with neurological deficits. *Developmental Neurorehabilitation, 12*(6), 421-426.

Wilson, B.A., Gracey, F., Evans, J.J., & Bateman, A. (2009b). *Neuropsychological Rehabilitation: Theory, Models, Therapy and Outcome.* Cambridge: Cambridge University Press.

World Health Organization. (2001). *International classification of functioning, disability and health (ICF)*. Geneva: WHO.

World Health Organization. (2007). *International classification of functioning, disability and health - Child and Youth Version (ICF-CY)*. Geneva: WHO

Wright, I., & Limond, J. (2004). A developmental framework for memory rehabilitation in children. *Pediatric Rehabilitation, 7*(2), 85-96.

Ylvisaker, M., Hanks, R., & Johnson-Green, D. (2003), *Rehabilitation of Children and Adults With Cognitive-Communication Disorders After Brain Injury* [Technical Report]. American Speech-Language-Hearing Association: available from www.asha.org/policy

Ylvisaker, M. & Feeney, T. (2002). Executive functions, self-regulation and learned optimism in paediatric rehabilitation: a review and implications for intervention. *Developmental Neurorehabilitation, 5*(2), 51-70.