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Evidence-based systematic review of cognitive rehabilitation, emotional, and family treatment studies for children with acquired brain injury literature: From 2006 to 2017

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Running Head: ABI children treatment

**An Evidence-Based Systematic Review of Cognitive Rehabilitation, Emotional, and
Family Treatment Studies for Children with Acquired Brain Injury**

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ABSTRACT

This paper updates guidelines of effective treatments for children with acquired brain injury (ABI) by including new evidence found in recent years and by building upon evidence presented in 2007. A systematic search was conducted for articles published from 2006-2017. Full manuscripts describing treatments of children (post-birth to 18) with acquired brain injury were included if study was published in peer-reviewed journals and written in English. Two independent reviewers and a third, if conflicts existed, evaluated the methodological quality of studies with an Individual Study Review Form and a Joanna Briggs Institute (JBI) Critical Appraisal Checklist. Strength of study characteristics was used in development of practice guidelines. Fifty-six peer-reviewed articles, including 28 Class I studies, were included in the final analysis. Established guidelines for writing practice recommendations were used and 22 practice recommendations were written with details of potential treatment limitations. There was strong evidence for family/caregiver-focused interventions, as well as direct interventions to improve attention, memory, executive functioning, and emotional/behavioral functioning. A majority of the practice standards and guidelines provided evidence for the use of technology in delivery of interventions, representing an important trend in the field.

Key Words: acquired brain injury, rehabilitation, cognitive rehabilitation, evidence-based systematic review, children

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Abbreviations: ABI=acquired brain injury, ACRM=American Congress of Rehabilitation Medicine, ACT=Acceptance and Commitment Therapy, Amsterdam Memory and Attention Training for Children=Amat-c, BRIEF=Behavior Rating Inventory of Executive Function, BRIEF-MI=The Behavior Rating Inventory of Executive Function Metacognitive Index, CAPS=Counselor Assisted Problem-solving, CBT=cognitive behavior therapy, COPM=Canadian Occupational Performance Measure, CO-OP=Cognitive Orientation to daily Occupational Performance, CRP=Cognitive Remediation Program, EBR=Evidence-Based Review, FPS = Family Problem-solving, IRC= Internet Resource Comparison, SSTP=Stepping Stones Triple P, SMART=Strategic Memory Advanced Reasoning Training, TBI=traumatic brain injury, TOPS= Teen Online Problem-solving, TOPS-TO=Teen Online Problem-solving–Teens Only, WM=Working Memory

Introduction

In 2007 a diverse group of treatment providers, members of the American Congress of Rehabilitation Medicine (ACRM), published an Evidence-Based Review (EBR) evaluating the effectiveness of cognitive rehabilitation and behavioral treatments for children with acquired brain injury (ABI) ^[1]. The present EBR updates this evidence related to effective treatment published over the past decade. As in the initial review, a multidisciplinary group including direct treatment providers and researchers conducted the EBR, employing analogous data search and evaluation components of the study.

In the initial study by Laatsch et al. ^[1] 28 studies met criteria for full evaluation after a search of peer-reviewed English-language publications from 1980 to 2006. Two practice guidelines were developed: one practice guideline for involving family members as active treatment providers and one practice option for attention remediation.

Nevertheless, there continues to be great need for the identification of effective treatments for rehabilitation of children following ABI. For example, Fuentes et al. ^[2] conducted a longitudinal cohort study examining the unmet needs of children following traumatic brain injury (TBI) during the first two years after injury. They reported that children with brain injuries generally have persistent, unmet functional needs across multiple domains and should be monitored closely for unresolved functional impairments. Increased time post-injury and a diagnosis of complicated mild TBI were

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associated with unmet therapy needs, particularly in the areas of cognition and communication.

Since 2007 there has been a consistent accumulation of studies examining treatments hypothesized to be effective in children with ABI [3, 4] [5, 6]. Most reviews commented on the limited number of studies and scarcity of Class I studies. Recently, Retsch et al. [4] reviewed the literature (from 1966-current) to determine what components of cognitive rehabilitation interventions were effective in children with ABI. Twenty studies were found to meet their criteria, but the authors did not classify the studies using EBR techniques. Instead, they summarized intervention details, intervention settings, and intervention frequency. Results were rated according to improvements in level of function, academic outcomes, and psychosocial functioning. All of the Resch et al. [4] studies, which met our inclusion and exclusion criteria, are included in this EBR.

Linden, Glang, and McKinlay [7] performed a systematic review and meta-analysis, using randomized control trial (RCT) class I studies, to examine educational interventions for children with ABI. While three studies met their meta-analysis criteria, there were no significant differences between educational intervention and control conditions on academic achievement. Even though many interventions have been developed, researchers are generally not measuring the impact of these interventions on academic

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outcome.

Thus, despite the acceleration of research regarding treatment interventions for children with ABI, there remains a significant need to improve and develop specific treatments. Reviewers' purpose is to summarize and report on a full range of cognitive rehabilitation and emotional/behavioral treatments published between 4/2006-12/2017^[8]. This study identifies effective cognitive rehabilitation and emotional treatments for children with ABI and supports the evolution of practice guidelines to assist treatment providers, educators, and family.

Methods

Search strategy: This systematic review is reported in accordance with the PRISMA Systematic Review and Meta-Analyses guidelines^[9]. The published literature was searched stepwise using strategies created by a medical librarian for the concepts of rehabilitation, children, and ABI. Key words were implemented in five databases (Figure 1). A total of 1088 studies were found. Two studies were added via hand search. Twenty-eight duplicates were found using an automatic duplication finder and an additional eight duplicate records were discovered manually and removed leaving 1054 unique citations in the project library.

Inclusion and exclusion criteria: 1) Publication: full manuscripts (abstracts, brief reports not included) published from 4/2006-12/2017; 2) Population: TBI, concussion, brain

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trauma, brain tumor and associated treatments excluding stroke, epilepsy, cerebral palsy, malaria, brain infections; 3) Age: Post-birth through age 18 years; 4) Intervention: Documented in the paper, can include those provided by therapist or technology. Treatment domains used were, attention & memory, comprehensive, emotional control and CBT, executive functioning, family/caregiver, language/academic, motor, technology; 5) Outcome: must be measured systematically and empirically; 6) Language: English.

Data extraction: The first two authors examined and agreed upon each unique citation for inclusion/exclusion criteria, after which 100 articles remained. Based upon the specifics of the intervention, these articles were grouped into eight treatment domains. Because these articles encompassed a wider range of interventions than those included in the 2007 study, three new treatment domains were introduced, including Technology, Family/Caregiver, and Motor. Technology interventions were identified when the majority of the treatment involved computer-based therapy with limited face-to-face therapist intervention. If intervention focused on motor-related cognitive skills, it was placed in the Motor domain. Similarly, if treatment focused on providing behavioral and emotional support to family/caregivers, the citation was placed in the Family/Caregiver domain. The Emotional Control/CBT domain incorporated both emotional control treatment and cognitive behavior therapy (CBT). The Comprehensive domain included studies that integrated multiple modalities of rehabilitation.

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Sixteen reviewers, two for each domain, proceeded to review the full studies. Reviewers confirmed that each study met established inclusion/exclusion criteria. This step reduced the number of qualifying studies to 56 (Table II). Since no studies in the language/academic domain met inclusion criteria, no articles were classified from this domain.

Classification of Studies: This step was conducted using DistillerSR, a web-based systematic review tool ^[10]. Using DistillerSR assured that review and classification of qualifying studies were performed independently. The first author provided support and monitored the online progress of the reviewers. Reviewers completed two standardized forms for each article in their treatment domain: the Individual Study Review Form ^[11] and a JBI Critical Appraisal Checklist to assist with detection of study bias and evaluate quality of evidence ^[12]. Reviewers classified each study as providing Class I, II, or III evidence based on the Individual Study Review and JBI forms; Class I evidence was assigned to prospective, properly designed, randomized, controlled trials, Class II evidence to prospective, non-randomized cohort studies, retrospective non-randomized case control studies, or clinical series with well-designed controls, and Class III evidence to clinical series without concurrent controls and case studies.

DistillerSR filtered the individual responses from the two treatment domain reviewers. The first two authors examined the data for conflicts in the classification of studies and

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quality of evidence. One of the two first authors communicated with both reviewers in a given domain to discuss identified conflicts and act as a third reviewer when required.

All conflicts were resolved and the classification results are provided in Table II.

Practice recommendations were developed using the standards proposed in the Clinical Practice Guideline Process Manual ^[13] and the adult cognitive rehabilitation EBR by Cicerone et al. ^[11] (Table III). Evidence based treatment recommendations were developed by the reviewers using specific qualifications: 1) A practice standard required strong evidence from at least one Class I study with additional support from a Class II or III study. 2) A practice guideline required a well-designed Class II study or Class I study/studies with methodological limitations. 3) A practice option required evidence from weaker Class I or II studies that address the effectiveness of the treatment directly and could be considered an option while treating children with ABI.

Results

Attention and Memory: Twelve studies evaluating attention and memory interventions were reviewed: 4 Class I, 2 Class II, and 6 Class III.

The first Class I study was a multicenter, randomized clinical trial ^[14] evaluating the Cognitive Remediation Program (CRP) of massed practice, strategy acquisition, and cognitive behavioral interventions. 161 children with attentional disturbance secondary to ABI were assigned to a 20-session CRP or wait list control group. The CRP group had

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statistically significant improvements in academic achievement and parent-reported attention compared to controls, and acquired significantly more metacognitive and learning strategies. There were no significant differences on neuropsychological tests, despite trends in the CRP group.

An additional class I study ^[15] examined long-term effects of an attention and memory training program for children with ABI six months after an initial study ^[16] in which 38 children were randomly assigned to treatment or control groups. Children in the treatment group received the Amsterdam Memory and Attention Training for Children (Amat-c), a multi-component intervention involving process-specific training and metacognitive strategy training supervised by a coach, with weekly feedback meetings with a psychologist or special education teacher. As noted immediately after treatment, at six-month follow-up, participants in the treatment group maintained significant improvements on neuropsychological measures of sustained attention, selective attention, and verbal and visual memory compared to control participants.

In a single-blinded Class I pilot study ^[17], 20 adolescents with a gist processing deficit after mild, moderate, or severe TBI were pseudo-randomized into a Strategic Memory Advanced Reasoning Training (SMART) or control group of memory strategy training. The intervention group had statistically significant improvements in abstraction, interpretation, and recall.

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The final Class I randomized controlled trial included 17 children after mild, moderate, or severe TBI ^[18] with self- or parent-reported attentional deficits. Participants were randomly assigned to the Ready! Set? Let's Train! group or control group. Treatment participants reported improved attention and performed significantly better on measures of working memory, inhibition, and cognitive flexibility.

The first Class II study evaluated table-top tasks and RehaCom or Attenzione e Concentrazione ^[19] respectively, depending on age, in 65 children with severe TBI and persistent attention deficits. Comparison of pre/post neuropsychological testing demonstrated improvements in verbal, visual, and overall IQ, sustained attention, and adaptive skills. Compared to a non-treatment group, the intervention group demonstrated a significantly greater recovery in sustained attention and adaptive skills.

The second Class II study evaluated two forms of errorless learning compared to trial-and-error learning in 15 children with TBI and 15 matched controls ^[20]. After a 20-minute delay, those with TBI performed best under errorless learning conditions; no differences were found in the control group.

The remaining 5 Class III studies evaluated a variety of interventions in various patient populations and reported improved neuropsychological performance, parent ratings, and daily life skills following participation in attention training after TBI. Results of

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several studies have to be interpreted with caution, however, due to inclusion of mild TBI (mTBI).

Recommendations: Based on results of one Class I study and data from Class II and III studies, attention process training (CRP) is a *practice standard* for children and adolescents following ABI. Based on the results of a related Class I study, process-specific attention and memory training paired with metacognitive strategy training (Amat-c) is a *practice standard* for children and adolescents with ABI. Based on results of one Class I study, gist reasoning is a *practice guideline*. Studies highlight the need for more stringent inclusionary criteria, particularly as related to mild TBI.

Comprehensive: Only one study met criteria for the comprehensive subdomain. This Class III study ^[21] was a mixed methods case study of music therapy for responsiveness and agitation. The participant was a 10-year-old girl with an acute, severe TBI. She received 10 music therapy sessions over 14 days. A qualified music therapist provided therapy. Based upon the girl's behavioral responses, the therapist adapted his tempo, volume, vocal timbre, and guitar accompaniment to increase the girl's responsiveness and decrease her agitation. Qualitative behavioral analysis identified brief but consistent periods in which the girl displayed increased awareness and responsiveness to the musical stimuli. Quantitative rating of the girl's agitation using the Agitated Behavior Scale produced inconclusive results due to poor inter-rater reliability.

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Recommendations: Only one comprehensive treatment study meet criteria and it was a Class III study. Therefore there is insufficient evidence to make recommendations regarding specific comprehensive treatments for children with ABI. Additional studies of comprehensive treatments are needed.

Emotional control and CBT: Seven studies met criteria for the emotional control domain: 3 Class I, 1 Class II, and 3 Class III.

Two class I studies ^[22, 23] examined efficacy of 8 biweekly and 4 supplemental family-based, counselor-assisted problem-solving sessions (CAPS). These studies included the same sample of 132 children who were 1-6 months post moderate-to-severe TBI and their parents. Families were randomized to either CAPS (n=65) or active internet-resource comparison (IRC) control (n=67)^[14]. Treatment participants had one in-home session, followed by all telehealth sessions. Parent-reported behavioral outcomes ^[22] and parent-reported social competence levels ^[23] were examined. Older adolescents enrolled in CAPS had greater improvements in externalizing behaviors than those enrolled in IRC ^[22]. Compared to controls, younger, moderately injured adolescents and older, severely injured teens manifested most improvements in social competence ^[23]. Lower pre-treatment executive dysfunction and higher IQ were associated with greater gains in social competence.

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A third Class I study ^[24] explored collaborative care (including care management, CBT, and psychopharmacological consultation) for improving post-concussive symptoms in teens with sport-related mild TBI using self- and caregiver-reports of concussion symptoms, depression, anxiety, and functional status. Adolescents assigned to collaborative care, compared to controls in usual care, showed significant reduction in post-concussive and depressive symptoms and functional improvement at 6 months follow-up. While collaborative care showed promise, efficacy of separate components was not explored.

The single Class II study ^[25] was a controlled-no treatment, non-randomized trial of CBT targeting disruptive post-TBI neurobehavioral and affective symptoms in 40 post-acute participants (4-18 years of age) with mild, moderate, and severe brain injuries (78% male). Despite limitations, only children in treatment had improved adaptive social skills and reduction in intensity of psychological symptoms.

Two Class III studies were multiple baseline, subject-own-control implementations of individualized, multi-component cognitive behavioral interventions ^[26, 27] for improving behavioral self-regulation. Cases were boys with severe TBI (ages 6 and 17). Educators and family were trained to implement executive functioning supports. Behavioral improvements were observed in each case, suggesting that teaching everyday people in the child's life to assist and support self-regulation may help children with TBI reduce disruptive behaviors.

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A final Class III study ^[28] using a pre-post, non-randomized, uncontrolled design, implemented 4-module CBT to improve post-concussive symptoms in adolescents with TBI. Following treatment, children showed reductions in post-concussive symptoms and improvements in quality of life.

Recommendations: Based on the results of two Class I studies on CAPS intervention, family-based problem-solving therapy is a *practice standard* for older adolescents following TBI. Based on the results of the one Class I study on collaborative care, and supporting Class II, and Class III study findings, CBT may be effective and should be a *practice guideline* for adolescents following TBI. Class III study findings suggest that helping teachers, classroom aides and caregivers develop individualized behavioral interventions is a *practice option* for school age children. Studies reviewed highlight the need for larger trials to test efficacy of interventions for improving a wide range of post-TBI problems children experience. Future investigators should enroll and randomize children with smaller age ranges, use active control groups, and ensure enough power to detect variations by gender, ethnicity, and severity for improving quality of evidence from trials.

Executive Functioning:

Eleven studies were reviewed within this domain: 4 Class I, 2 Class II, and 5 Class III. Four Class I studies addressed executive functioning (EF) in adolescents with TBI utilizing

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internet-based programs ^(29, 30, 31, 45). The first of which by Wade and colleagues in 2010 ^[29] utilized a teen online problem-solving program (TOPS) with 41 adolescents. TOPS consisted of cognitive-behavioral and skill-building interventions and were compared with an internet-resource control ^[14]. Significant improvements on an executive symptom scale (BRIEF) and self-reports in severe TBI were observed, while those with moderate TBI lacked significant change. Group differences, especially in older children, were greater on the metacognitive skills, including working memory skills, monitoring, and organizational skills.

Two additional Class I studies by Kurowski et. al ^[30] and Karver et. al ^[31] blindly randomized 137 and 132 adolescents, respectively, all with mild to severe TBI into a web-based counselor assisted problem-solving (CAPS) intervention or IRC group. CAPS consisted of counselor-assisted, web-based, family-centered interventions focused on training problem-solving, communication, and self-regulation. Parental-based outcome measures were compared. Kurowski found significant improvements on the BRIEF for high schoolers in the CAPS group. Karver et. al ⁽³¹⁾ is an adjunct study, randomly assigned to CAPS or IRC and administered a vocabulary measure from an intelligence test. Comparing post-treatment scores, verbal intelligence was associated with greater executive function improvements in the CAPS treatment group.

Two Class II studies described executive interventions using clinical trials. Treble-Barna et al. ^[32] treated children for 10-weeks using a combination of computer-assisted

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attention training tasks and metacognitive strategies. Goal attainment scaling was used to select real life tasks to which the learned strategies would be applied. Compared with non-treated healthy controls, the treatment group demonstrated significant improvements in sustained attention and on the BRIEF. Chan and Fong^[33] trained children on problem-solving skills using metacognitive strategies. Children received explicit problem-solving training twice weekly for 7 weeks. Compared with a waiting list control group, those who received problem-solving training demonstrated significant improvements on measures of the components of metacognition, defining the problem, generating alternatives, implementing strategies, and evaluating outcomes. The treatment group also showed improvement on the BRIEF and every-day life performance using the Canadian Occupational Performance Measure (COPM).

Five Class III executive functioning studies were reviewed. One explored the idea of training "everyday people" to act as "cognitive coaches" for children in their application of goal management training in everyday activities^[34]. A second study focused on computer-based exercises designed to improve cognitive flexibility, attention, and working memory and demonstrated a correlation with frontal lobe fMRI activation^[35]²⁰¹¹. A third supported the ease of use and acceptability of a web-based videoconference training program of a problem-solving intervention to family identified goals^[36]. Two pilot studies were also reviewed; a combined cognitive behavioral and psycho-educational treatment approach^[37] and a preliminary model for improving self-awareness among children in a group based pilot study^[38].

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Recommendations: Three Class I studies, demonstrating the efficacy of online interventions in improving executive functioning strategies for problem-solving, communication, and self-regulation, especially in older children provided strong support for this intervention as a *Practice Standard*. A *Practice Guideline* was supported by two strong class II studies that showed effectiveness of the training of metacognitive strategies to improve executive function in children. A second *Practice Guideline* was identified for using guided internet-based interventions in younger children evidenced by Class I studies and supported by Class III studies. Several Class I and Class III studies support a *Practice option* for the feasibility of home-based cognitive rehabilitation training on training on Goal Management Training (GMT) with monitoring and interventions through video conferencing. Most studies used parental measures and self-reports as outcome measures. Future research should focus on optimal timeframe for intervention and include performance-based outcomes demonstrating the effects of executive functioning training in everyday life activities, including school and home functioning.

Family/Caregiver: Twelve studies met criteria for the family, caregiver, and teacher intervention subdomain: 11 Class I and 1 Class II.

The first Class I study^[39] examined the efficacy of a family intervention, Stepping Stones Triple P (SSTP) combined with Acceptance and Commitment Therapy (ACT), on parent-

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family adjustment. 59 parents of children with TBI were assessed. Participants were randomly assigned to a care-as-usual control group (n=29) or the SSTP treatment group (n=30). SSTP was delivered over 11 sessions. Results of outcome questionnaires demonstrated improvements in parenting confidence, family functioning, psychological distress, and couple disagreements for the SSTP group.

One Class I study involved the use of a family-centered problem-solving intervention (FPS) to evaluate family outcomes following TBI ^[40]. Families of 32 children with moderate/severe TBI were randomly assigned to the FPS treatment (n=16) or the usual care control group (n=16). Treatment families reported better parent-child relationships and improvement in child behavior after receiving 7-11 sessions focused on problem-solving and skills training. Another Class I study ^[41] used an online FPS intervention to evaluate child adjustment. Families of 39 children with moderate to severe TBI were randomly assigned to the FPS group (n=20), which received 14 online sessions, or an IRC ^[14] control group (n=19). Results of parent-report measures for FPS indicated improvement in child self-management and compliance.

Seven Class I studies involved the use of an online Counselor-Assisted Problem-Solving (CAPS) intervention to evaluate family outcomes following TBI in adolescents ^[31, 40-45]. These studies sampled 132 families of adolescents 1 to 7-months post-hospitalization for ABI. Families were randomly assigned to CAPS (n=65) or an IRC control group (n=67). Treatment participants had one in-home session, followed by 7-11 videoconferencing

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sessions. Results demonstrated improvement in parent-reported conflicts with adolescents and increased adolescent problem-solving, improvement in adolescent externalizing and internalizing behaviors ^[22], and improvement in adolescent functional outcomes within the treatment group ^[45]. Results also indicated reduced rates of caregiver psychological distress ^[42] and decreased parent depression ^[44]. Another Class I study evaluated the effect of parental marital status on participation in the CAPS intervention. Results demonstrated that marital status moderated treatment effects on adolescent externalizing behaviors ^[43].

A final Class I study ^[47] involved the use of a Teen Online Problem-Solving–Teens Only (TOPS-TO) intervention to evaluate feasibility and benefits as compared to a TOPS–Family (TOPS-F) intervention. 152 adolescents with moderate to severe TBI were randomly assigned to TOPS-TO, TOPS-F, or an IRC control group. Treatment participants received 10 core and 8 supplemental online sessions. Results indicated feasibility of the TOPS-TO intervention; however, adolescents in the TOPS-F group endorsed closer parent-adolescent relationships.

The only Class II study ^[48] used a pre/post single group design to evaluate an individualized consultation program, BrainSTARS, for parents and school personnel. 30 children with TBI participated in the study, and parents and school personnel received 3 consultation meetings. Results of the study indicated that the BrainSTARS program may increase parent and teacher proficiencies in addressing the needs of children with ABI.

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Recommendations: Based on the results of the Class I studies on CAPS and family-centered interventions; family-based problem-solving therapy is a *practice standard* for families of children and adolescents following ABI. Based on the results of the TOPS-TO study, teen-only problem-solving interventions are a *practice guideline*. Based on the results of the one Class II study, individualized consultation programs for parents and teachers should be a *practice guideline* for children and adolescents with ABI.

Motor: Two studies, both Class III, met criteria in this domain. The first is that of Missiuna et al. ^[49]. This study investigated the Cognitive Orientation to daily Occupational Performance (CO-OP) approach of metacognitive strategy training among children with TBI and found that these children showed a significant improvement in ability to complete functional activity-based tasks ^[49]. The second Class III study is that of Zlotnik and colleagues ^[50]. This study investigates the Dynamic Interactional Model and Expanded Awareness Model of Togliola ^[51, 52] and found that the model assisted in improving self-care and mobility as well as assisted in identifying awareness of possible deficits in these areas for this two case series ^[50].

Recommendations: Based on two Class III studies, with limited participants, there is insufficient evidence to make recommendations regarding specific motor/functional activity based treatments for children with acquired brain injury. Additional studies are needed in this area.

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Technology: 11 technology-based studies met inclusion criteria: 6 Class 1 and 5 Class III.

All Technology studies had relatively small sample sizes ranging from 1 to 40 participants.

Researchers presented Class I evidence of Cogmed™ adaptive training for working memory ^[53] in 13 children with moderate to severe TBI by investigating the contribution to improvements in WM, attention, reading, and mathematics ^[54]. Children in the training condition (15 session/activity) were compared to a placebo condition. Findings showed that children who received Cogmed™ made improvements in aspects of WM and reading, but not attention and mathematics.

Several studies examined online home-based interventions for Family Problem-solving (FPS) and Teen Problem-solving (TOPS) ^[41, 55, 56]. In a pilot Class I study, the FPS intervention was employed to improve parents' mental health following child's TBI ^[40]. Parents were randomized to the FPS (n=20) or IRC ^[14] group (n=20) for 14 sessions. Findings showed reduced distress, depression, and anxiety in parents. A second Class I study expanded the FPS intervention by including training in executive functioning and language pragmatic skills in the TOPS program ^[55]. Five families received the TOPS intervention with accompanying audio while four received a no-audio condition for 16 sessions. At follow-up, group improvement was observed for the audio condition in internalizing problems, parent depressive symptoms, and parent-adolescent conflict. A subsequent Class I study compared adolescents aged 11-18 years with moderate to

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severe TBI who underwent 16-20 sessions of TOPS with an IRC control group^[57]. TOPS contributed to improvements in parent-teen conflict resolution. A follow-up paper described findings from the parents' perspective to be improvements in problem-solving skills and depressive symptoms, particularly in families from lower income households [56].

Examination of the NeuroPage system for compensation of memory and planning difficulties, worn by the child for 5-7 weeks, was examined in 12 children with neurological deficit [58]. In this Class I cross-over trial, all participants made improvements in conducting everyday tasks at follow-up.

Recommendations: Based on results from online self-guided interventions targeting adolescent behavior, parent support, and online practice of cognitive skills, technology interventions can offer a *practice guideline* for children and adolescents following TBI. A class III study found that helping teachers, classroom aides, and caregivers develop context-sensitive, individualized interventions in the home and classroom setting is a *practice option* for school aged children to improve independence in self-monitoring and social participation. Studies reviewed highlight the need for more trials with larger samples across age ranges to test efficacy of interventions for improving a wide range of post-TBI cognitive and behavioral problems.

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The review of technology products for cognitive rehabilitation shows that skills can be improved, but complete understanding of transfer of these improved skills to functioning in everyday life and academic performance is limited. Availability of features in smartphones and children's pre-injury experience with technology provide a means to compensate for acquired cognitive and emotional impairments that has potential to increase self-management and independence.

DISCUSSION

Summary of evidence: The present study yields the largest EBR of cognitive and behavioral interventions for children with ABI to date, outlining evidence for 8 *practice standards*, 11 *practice guidelines*, and 3 *practice options* (see Table III). Clinicians can use these findings to guide provision of services to children with ABI, and researchers may use these findings to target future studies to bolster the strength of evidence in this paper. This EBR presents 28 Class I studies and subsequent *Practice Standards*, as well as an advanced, systematic literature search conducted by a medical librarian. The previous EBR ^[1] searched 2 databases using a total of 11 search terms. By comparison, the present EBR searched 5 databases using a total of 37 search terms/concepts. Another strength of this study was the use of a web-based systematic review tool (DistillerSR), ensuring objectivity through blinded, independent reviews.

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The strongest evidence pertained to family/caregiver-focused interventions including SSTP, FPA, and CAPS. The previous EBR ^[1] presented evidence of family/caregiver-focused intervention which provided a single practice guideline. The dramatic increase in high quality research on family/caregiver interventions over the past decade resulted in four *practice standards* and two practice guidelines. These very strong findings implicate family/caregiver training and/or involvement as a “core component” to successful cognitive/behavioral rehabilitation in children with TBI. Indeed, evidence from other domains reviewed throughout this EBR supports the notion that family/caregiver involvement and teaching “everyday people” in the child’s life in assisting self-regulation can improve outcome ^[22, 23, 26, 27].

There was also strong evidence for attention and memory interventions, yielding two *practice standards*, specifically for attention process training (APT) and Amat-c, as well as one *practice guideline* for gist reasoning (e.g., SMART). These findings clearly reflect strong efficacy for attention and memory interventions in general, as well as the specific programs employed in the studies. Compared to the previous EBR ^[1], the present EBR represents extensions of studies included in the 2007 EBR ^{[59] [16]}, reflecting continued advancement of attention rehabilitation in pediatric populations over the past decade.

For the domain of EF interventions, there were *practice standards* for TOPS and CAPS, *practice guidelines* for training of metacognitive strategies and guided internet-based interventions in younger children, and a *practice option* for the feasibility of home-

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based cognitive rehabilitation training with clinician monitoring via videoconferencing. This represents a new area of study since the prior EBR, in which there were no specific EF interventions.

Regarding emotional/CBT interventions, this EBR found evidence for three recommendations: family-based problem-solving therapy (CAPS) as a *practice standard* for older adolescents following TBI; a *practice guideline* for CBT for adolescents; a *practice option* for interventions that assist “everyday people” (e.g., teachers, caregivers) to develop context-sensitive, individualized interventions in the classroom setting for school-age children with TBI. This reflects improved quality of studies compared to those included in the previous EBR, at which time all of the emotional/CBT studies were of single-subject design methodology^[1].

There is strong evidence to support technology-based interventions, including five *practice guidelines* and one *practice option* for self-guided, web-based intervention programs, including TOPS, FPS, Neuropage, and CogMed™. These programs target several domains covered in previous sections (e.g., EF, family problem-solving, social), but are unique in that they are completely self-guided by the patient via internet/computer/tablet. An obvious advantage of this modality is the increased accessibility for patients who live remotely or for families who, due to practical constraints (e.g., work schedule, transportation), are unable to attend frequent therapy appointments. This also reflects trends of the modern era, as many children are

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considered “technology natives,” meaning they have been raised in the digital age. Current cell phone technology offers features such as calendars, alarms, enhanced digital displays, and word processing platforms that teens can use for training and management to improve cognitive and behavioral skills. Potential disadvantages of these interventions are related to the fact that they are completely self-guided. Youths with executive deficits are likely to struggle more with self-guided tasks that require initiation and self-monitoring. Thus, absence of a rehabilitation therapist overseeing the patient’s progress may leave the child open to errors that are inherent to his/her brain injury (e.g., anosognosia). Furthermore, review of technology products for cognitive rehabilitation shows that skills can be improved but understanding of transfer/generalizability of these improvements to daily functioning and academic performance is limited.

Beyond the studies included in this EBR, evidence for the efficacy of CogMed in children with ADHD has been inconsistent ^[60, 61], and has been critiqued as lacking generalizability ^[62, 63]. The methodology of the single Class I study in this EBR used objective cognitive/neuropsychological and academic achievement measures as outcome variables but did not assess for improvements in everyday functioning. Further research is needed to better understand the impact of technology-based interventions on functional skills.

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There was only one comprehensive program study included in this EBR, which is in contrast to the eight comprehensive studies in the previous EBR ^[1]. This may reflect the recent trend of studies to target specific domains, such as family/caregiver and technology-based research, which accounts for many studies in the current EBR.

Alternatively, it should be mentioned that there are strong comprehensive programs that were not covered in this EBR simply due to the narrow inclusion criteria ^[64] ^[65].

Future research may focus on comprehensive programs with well-defined clinical populations.

Study Limitations

Limitations of this EBR pertained to the stringent inclusion criteria, which excluded many strong studies in the pediatric literature. The inclusion criteria were intentionally narrow in order to limit heterogeneity of participant population and to limit the vast number of studies across all pediatric clinical populations. Despite these efforts, heterogeneity could not be avoided. Two Class I attention & memory studies ^[17, 18] were limited by heterogeneity of clinical populations, since a significant portion of participants in these studies had mTBI (i.e., concussion). Previous research has consistently shown that mTBI does not result in long-term cognitive impairments ^[66, 67] ^[68] ^[69, 70]; most adolescents recover in less than 3 months ^[71, 72] ^[73], and post-concussion cognitive complaints are often impacted by non-injury related factors ^[74-76]. Thus, “cognitive impairment” among participants with mTBI in these studies reported over six

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months post-injury was likely unrelated to injury. Accordingly, generalization to moderate/severe TBI must be considered with caution.

Few studies provided adequate data to guide comment on the influence of age and development on responsiveness to cognitive/behavior rehabilitation interventions. In general, metacognitive and/or self-guided strategies tend to be most efficacious in older adolescents ^[29, 44], whereas younger, school-aged children may benefit more from parent/teacher-guided interventions and increased environmental management in his/her everyday environment ^[26, 27]. There is evidence that family problem-solving interventions are effective in school-aged children ^[40] and adolescents (age 11-18)^[57]. While these trends in age/developmental-effect may seem intuitive, further research is needed to systematically assess variations in intervention and/or modality on treatment efficacy in children of different developmental levels.

Conclusions

The present EBR presents numerous *practice standards* and *practice guidelines* for family/caregiver involvement and interventions, as well as for direct interventions improving attention, memory, EF, and emotional/behavioral functioning. Integration of technology into treatment delivery shows promise, though further research is needed to ensure generalizability across environments. Differences in treatment provisions may be necessary for different age-ranges, though further research is needed in this area as well.

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Figure I: FLOW CHART - Provides the number of manuscripts under review at each stage of the search process using PRISMA guidelines^(8,9)

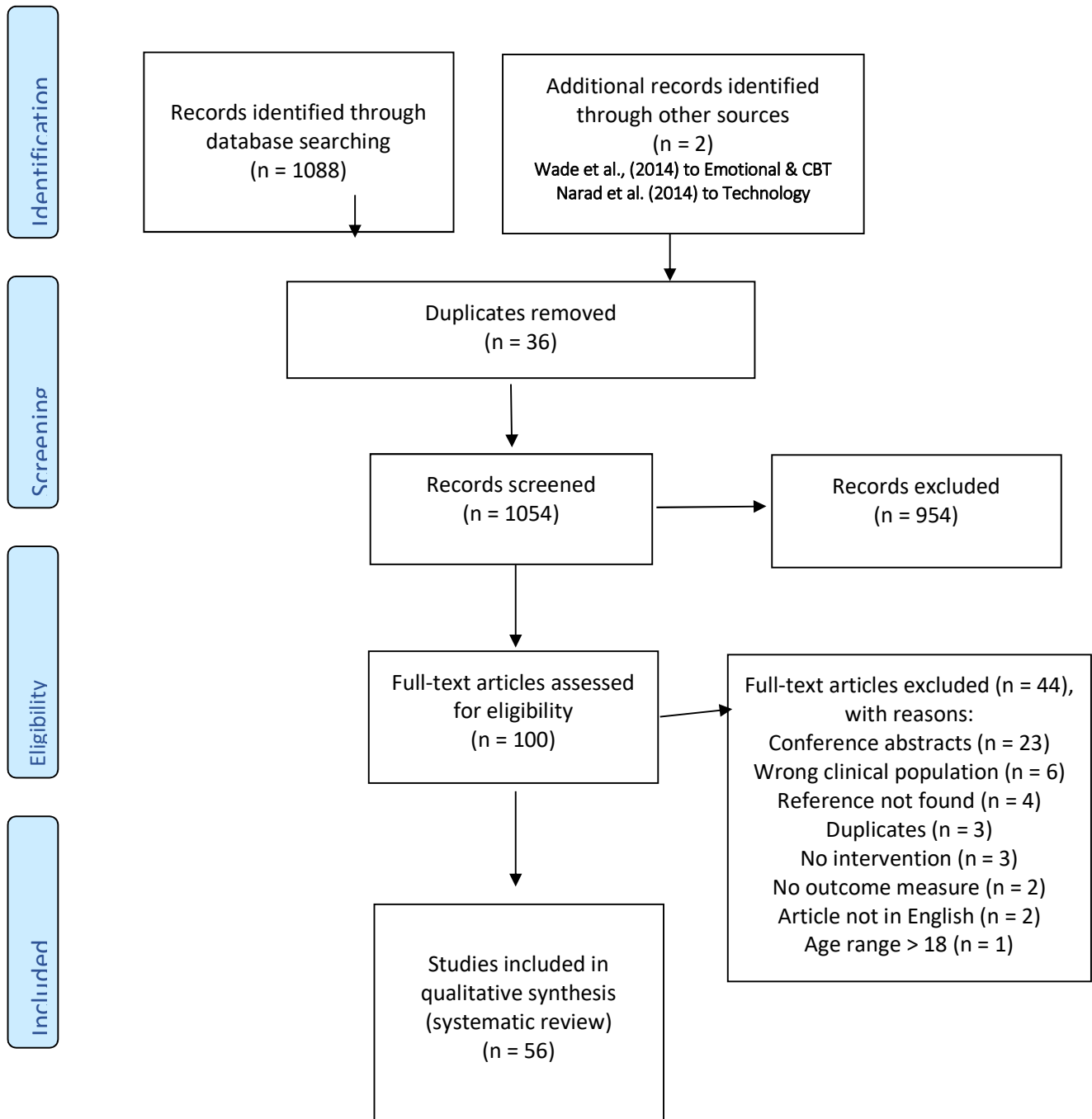


Table I: Search strategy and terms: completed December 2017

DATA BASES: Embase 1947-current, Ovid Medline 1946-current, Scopus 1823-current, PsycINFO 1880s-current, and clinicaltrials.gov 1997-current
INITIAL SEARCH TERMS: Cognitive rehabilitation, speech therapy, language therapy, attention training, cognitive remediation therapy, remediation training, cogmed, brainsteps, neuropsychological rehabilitation, working memory training, vocational rehabilitation, occupational therapy, memory training, memory training problem-solving
AND Pediatrics, child, adolescent, toddler, infant, teen, youth juvenile, pediatric, pediatry
AND Traumatic brain injury, brain lesion encephalopathy, cerebral lesion, brain system trauma, cerebral trauma, organic cerebral trauma, traumatic brain injury, posttraumatic encephalopathy, acquired brain injury, brain injury(s), cerebral injury(s), cerebrum lesion(s), left hemisphere injury, right hemisphere injury

Table II: Evidence-based classification of 56 studies meeting criteria

Treatment Domain	Authors	Year	Total Subjects Enrolled	Y/N Significant Results	Classification Given by Reviewers
Attention and Memory	Butler, R.W. et al. ^[14]	2008	161	Y	I
	Catroppa, C. et al. ^[77]	2016	10	Y	III
	Cook, L et al. ^[17]	2017	20	Y	I
	Coyne, J et al. ^[78]	2015	15	N	III
	Galbiati, S. et al. ^[19]	2009	65	Y	II
	Haslam, C et al. ^[20]	2012	30	Y	II
	Ho, J. et. al. ^[79]	2011	15	Y	III
	Kaldoja, M. et. al. ^[80]	2015	26	Y	III
	Sequin, M., et al. ^[18]	2018	17	Y	I
	Sjo, N et al. ^[81]	2010	7	Y	III
	Van't Hooft, T., et al. ^[15]	2007	38	Y	I
	Van't Hooft, T., et al. ^[82]	2010	3	N	III

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Comprehensive	Bower, J., Grocke, D, Shoemark, H [21]	2014	1	N	III
Emotional and CBT	Feeney [27]	2010	2	N	III
	Feeney [26]	2006	2	N	III
	McCarty, et al. [24]	2016	29	Y	I
	Pastore, V et al. [25]	2007	40	Y	II
	Tlustos, S. et al. [23]	2016	132	Y	I
	Wade, S. et al. [44]	2012	132	Y	I
	Kelly, A. et al. [28]	2017	31	Y	III
Executive Functioning	Catroppe, C and Muscara, F [37]	2009	3	Y	III
	Chan, D [33]	2011	32	Y	II
	Karver, C, et al. [31]	2014	132	Y	I
	Kesler, S. [35]	2011	23	Y	III
	Krasny-Pacini, A., et al. [34]	2014	5	Y	III
	Krasny-Pacini, A., et al. [38]	2015	5	Y	III

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	Kurowski, B., et al. [30]	2013	132	Y	I
	Treble-Barna, A., Harn, B., Wade, C. [32]	2016	24	Y	II
	Wade, S., et al. [45]	2017	153	Y	I
	Wade, S., et al. [29]	2010	35	Y	I
	Wade, S., et al. [36]	2009	9	Y	III
Family/ Caregiver	Brown, F., et al. [39]	2015	59	Y	I
	Dise-Lewis, J., et al. [48]	2009	30	Y	II
	Narad, M., et al. [46]	2015	132	Y	I
	Patranovich, C., et al. [42]	2015	132	Y	I
	Raj, S., et al. [43]	2017	129	Y	I
	Wade, S., and Brown, T. [40]	2006	32	Y	I
	Wade, S., Carey, J., Wolfe, C. [41]	2006	44	Y	I
	Wade, S. and Taylor, H. [44]	2014	132	Y	I
	Wade, S., et al. [22]	2014	132	Y	I

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	Wade, S., et al. [83]	2015	132	Y	I
	Wade, S., Cassidy, A., et al. [84]	2015	132	Y	I
	Wade, S., et al. [45]	2017	101	Y	I
Motor/Functional Skills	Missiuna, C., et al. [49]	2010	6	Y	III
	Zlotnik, S., et al. [50]	2009	2	Y	III
Technology	Dexheimer, J., et al. [85]	2017	8	N	III
	Janssen, J., et al. [86]	2012	1	N	III
	Kurowski, B., et al. [87]	2016	21	Y	III
	Phillips, N., et al. [54]	2016	27	Y	I
	DePompei, R., et al. [88]	2008	106		III
	Narad, M., Bedel, G., King, J. [47]	2014	4	Y	III
	Wade, S., Carey, J., Wolfe, C [41]	2006	40	Y	I
	Wade, S., Carey, J., Williams, K., [55]	2008	9	Y	I

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	Wade, S., et al. ^[57]	2011	41	Y	I
	Wade, S., et al. ^[56]	2012	42	Y	I
	Wilson, B., et al. ^[58]	2012	12	Y	I

Table III: Treatment domain, name and description of intervention, level of practice recommendation, specific limitation(s) in recommendation based on study elements

TREATMENT DOMAIN	NAME AND DESCRIPTION OF INTERVENTION	LEVEL OF RECOMMENDATION	SPECIFIC LIMITATIONS IN RECOMMENATION
Attention & memory	Attention Process Training (APT)	Practice Standard	Possible limited applicability to moderate and severe TBI given that mTBI participants without verified cognitive deficits were included
Attention & memory	Amsterdam Memory and Attention Training for Children (Amat-c): process-specific attention and memory training with metacognitive strategy training	Practice Standard	Small and heterogeneous ABI sample with significantly more children with brain tumors, possible experimenter effects due to three of the authors providing a portion of the intervention, active ingredients of the treatment not identified, no activities and participation-level outcome measures.
Attention & memory	Gist Reasoning	Practice Guideline	Possible limited applicability to

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			moderate and severe TBI given that mTBI participants without verified cognitive deficits were included
Emotional Control & CBT	Family-based problem-solving	Practice Standard	Need more information about specific treatment before treatment can implemented by clinicians; limited power to detect differences in subgroups (e.g., age, gender, SES)
Emotional Control & CBT	CBT	Practice Guideline	Class I study did not isolate effectiveness of CBT versus other intervention components
Emotional Control & CBT	Strategies to promote executive functions in the classroom	Practice Option	Only four cases were provided; highly intensive and individualized treatment; age range is wide
Executive Functioning	Online Based Problem-solving Interventions	Practice Standard	Expectation and selection bias may limit generalizability Measures of EF are based on self/family rating scales but not on actual measures of EF performance
Executive Functioning	Metacognitive Training; defining the problem, generating	Practice Guideline	Lack of long-term follow-up, unable to determine if gains are

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	alternatives, implanting strategies, evaluating outcomes		maintained over time, measures based on parent-child perception and not on actual problem-solving performance
Executive Functioning	Guided Internet-Based Interventions for younger population (i.e. Counselor Assisted)	Practice Guideline	Lack of long-term follow-up, unable to determine if gains are maintained over time, heterogeneous samples; unable to isolate effects of EF interventions, EF measures were based on self/family rating scales, should aim to use teacher reports and ecologically valid performance measure, small sample size
Executive Functioning	Home Based Cognitive Remediation Training, Goal Management Training and Video Conferencing/ Skype	Practice Option	For higher levels of evidence, future studies should address the following: Expand the role of parental coaching, increase duration of intervention, maintain direct contact with schools/teachers to reinforce goals and monitor progress
Family/Caregiver	Family behavioral intervention,	Practice Standard	Outcome measures dominated by self-

	Stepping Stones Triple P (SSTP) combined with ACT with an overall study aim to improve parent-family adjustment		report; some effects were not maintained at the six month follow-up; study did not take place in a rehabilitation setting; sample was largely Caucasian
Family/Caregiver	Family-centered problem-solving and skill building intervention (FPS). The overall aim of the intervention was to improve child behavior following TBI and improve family relationships.	Practice Standard	Small sample size with heterogeneity in injury severity; the control group received usual care only; outcome measures were dominated by self-report; the experience level of the therapist providing the intervention was not controlled
Family/Caregiver	Online FPS compared to an internet-resource control group. The main aim of the intervention was to improve child adjustment	Practice Standard	Relatively small sample size with more mild injuries over-represented in the sample; outcome measures were dominated by self-report; long-term follow-up was not completed
Family/Caregiver intervention	Problem-solving intervention, Teen Online Problem-solving – Teen Only (TOPS-TO). The objective was to improve teen satisfaction with a teen-only problem-solving intervention	Practice Guideline	Data regarding comparison efficacy between TOPS-TO and TOPS-F was not included; preference in treatment modality between parents and adolescents was not assessed; relatively small number of

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	involving parents following ABI.		nonwhite participants were included in the study
Family/Caregiver	Online Counselor-Assisted Problem-solving (CAPS), with the objective to improve family and parent outcomes following TBI in adolescents	Practice Standard	Outcome measures dominated by self-report; intervention focuses on adolescents with TBI only; all papers in this group emerged from the same study cohort/same investigators; the control group received internet-resource support only; optimal dosing not explored
Family/Caregiver	Individualized consultation program, BrainSTARS, designed for parents and school personnel to the needs of children with ABI in the school setting	Practice Guideline	Randomization not included in design; covered a wide age range with a relative small sample size for each age category; time-post injury was not controlled for related to the timing of the intervention
Technology-Working memory	COGmed™ program: working memory by manipulation and storage of verbal and/or visuospatial information	Practice Guideline	Applies to reading but not other academic subject areas.
Technology-Parent Adjustment	Web-based self-guided Family Problem-Solving therapy (FPS)	Practice Guideline	This directly addresses the treatment in question but does not demonstrate applicability to

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			cognition or cognitive rehabilitation
Technology-Adolescent and Parent psychosocial adjustment	Web-based self-guided Teen Problem-Solving therapy (TOPS): targets executive function, social skills and adolescent self-monitoring of behavior with parental support	Practice Guideline	The intervention resulted in improved adolescent internalizing behaviors and depression; however, generalization to cognition and cognitive rehabilitation was not described.
Technology-Problem-solving Skills	Web-based self-guided Teen problem-solving intervention (TOPS): executive function, social skills and adolescent self-monitoring of behavior with parental support	Practice Guideline	The intervention resulted in improved adolescent problem-solving and reduction in parent-teen conflicts; however, generalization to cognition and cognitive rehabilitation was not described.
Technology-Memory and planning for daily self-selected tasks	Individualized reminders for daily tasks automatically sent to a device (Neuropage)	Practice Guideline	Individualized reminders delivered via technology improve memory and planning for everyday tasks. The association between cognitive skills, cognitive rehabilitation and daily tasks requires further investigation.

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Technology-Independence and Participation	Methods which used APPS, the Nintendo Wii® and personal data assistants to promote independent behavior, individualized rehabilitation goals, reductions in post-concussion symptoms and social and behavioral functioning.	Practice Option	Technology interventions using aspects that children have experience with can improve self-monitoring, cognitive skills and social participation. Further investigation of the efficacy of technology type it needed.
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