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Evidence – Based Practice for Traumatic Brain Injury A Cognitive Rehabilitation Reference for Occupational Therapists

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Abstract

Traumatic brain injury is a growing public health concern. Nearly 1.7 million people in the United States sustain a TBI *each* year (Faul, 2010). Many of these individuals require cognitive rehabilitation from occupational therapists. We conducted a literature review to identify and summarize best, evidence-based practice for cognitive rehabilitation for everyday citizens who have sustained TBI. We excluded articles describing specific populations (pediatric, sports injury, comorbidities, combat specific), articles specific to a geographical location, and articles validating assessments. This manuscript describes a systematic review of recent (since 2006) TBI literature specific to the cognitive rehabilitation of everyday citizens.

We found that there *is* empirical evidence describing interventions for most cognitive domains affected in TBI, but much more research is needed. Scientific findings from related fields (e.g. neuroscience) were infrequently cited in occupational therapy literature but arguably relevant to TBI assessment and treatment. We summarized our findings so this manuscript could guide occupational therapists conducting cognitive rehabilitation. This manuscript was also designed to help identify the “gaps” in interdisciplinary cognitive rehabilitation literature. We addressed the concern of limited interdisciplinary research by suggesting potential solutions to this problem.

Keywords

TBI; Evidence-Based Practice; Cognition; Rehabilitation; Occupational Therapy; Interdisciplinary Systematic Review

Introduction

Imagine this scenario: an occupational therapist receives her schedule for a day at the rehabilitation hospital. She sees the list of names and diagnoses. She has thirty minutes to complete a chart review and make treatment plans. For the patients with physical injuries, her treatment plan is clear. She will help these patients increase flexibility, strength and utility of their limbs. She will provide adaptive equipment to compensate for the physical

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deficits that cannot be remediated. However, there is also a patient listed with traumatic brain injury. He needs cognitive rehabilitation so he can return home safely. She recognizes that rehabilitation should focus on improving his attention, learning, and memory, but she is uncertain of the best way to accomplish these goals. His injury is internal and invisible. She wants to assume that the activities he completes in his environment will make meaningful improvements to brain function. But how can she be sure? Do improvements during therapy translate to real-life functionality? At what time point does she assume that remedial approaches are futile, and compensatory interventions are best practice? What factors regarding patient management must be considered to predict optimal cognitive outcomes? What literatures can be tapped to address unexpected issues?

This vignette depicts some of the challenges facing those involved in the cognitive rehabilitation of people with traumatic brain injury (TBI). TBI is defined as brain damage that disrupts function in variable ways with diverse consequences (The Merck Manual of Diagnosis and Therapy, 2006). Nearly 1.7 million people in the United States sustain a TBI *each* year prompting 275,000 hospitalizations (Faul, 2010). Acutely, TBI severity is assessed using the Glasgow Coma Scale (GCS) with lower scores reflecting more severe injuries (Teasdale & Jennett, 1974). GCS scores can be grouped according to TBI severity: mild (13+), moderate (8–12), severe (<8) (Decuyper & Klimo, 2012). Perhaps surprisingly, there is no gold standard for cognitive rehabilitation (Gordon, 2011) and no systematic approach to cognitive remediation. Therapists, of course, use theoretical models to guide treatment, but empirical evidence can help expedite treatment and maximize gains. Without a systematic, evidence-based approach, a patient with TBI may receive varied cognitive interventions until one works, or until reimbursed rehabilitation ends.

There is no single TBI literature. Instead, physicians, nurses, neuropsychologists, therapists, researchers, and other professionals often publish research findings in specialty journals. This makes it nearly impossible to stay current with the literature(s). The purpose of this paper is to summarize the TBI literatures for the occupational therapist (OT). In short, this review is intended as a primer for busy OTs who conduct cognitive rehabilitation. Our secondary goal is to expand crosstalk between related fields as TBI is inherently interdisciplinary. In the subsequent sections we review issues that influence and improve cognitive recovery, such as successful early medical interventions, assessment, and empirically based cognitive rehabilitation strategies.

For this review, we screened 1200 articles in a PubMed search for recent (since 2006) papers relevant to TBI rehabilitation. More refined searches were completed for to identify themes relevant to each discipline (e.g. physicians, nurses, neuropsychologists, clinical psychologists, occupational therapists, physical therapist, speech and language pathologists, cognitive neuroscientists, and bioengineers). To focus on what happens in the general TBI population, we excluded articles describing specific populations (pediatric, sports injury, comorbidities, combat specific), articles specific to a geographical location, and articles validating assessments. Finally, although grant funding and research programs targets TBI in veterans and athletes, our goal was to highlight the consequences of TBI in civilians. In the review of these manuscripts, we noticed that the involved disciplines were conducting similar research but not referencing other fields. In other words, we saw a lack of

interdisciplinary work. As stated above, this manuscript is designed to integrate knowledge from multiple fields to serve as a cognitive rehabilitation reference for OTs. Additionally, we use this manuscript as a forum to address ways to improve interdisciplinary research and practice. We also note that to avoid excessive qualification through the manuscript, TBI is variable and there can be exceptions to the patterns described below.

Early Interventions: Intubation, Diagnosis, Surgical and Pharmaceutical Treatment

Early TBI management can predict the success of later cognitive rehabilitation. Indeed, a major cause of death and secondary brain injury in TBI is caused by first responders' difficulty establishing, securing, or maintaining an airway (Bauer, 2012) or performing resuscitation (Bernard et al., 2010). Air medical crews also have the responsibility of safe and rapid intubation under difficult, often complicated circumstances (e.g. cervical spine instabilities) (Bauer, 2012). Efficient endotracheal intubation, such as by video laryngoscopy, reduces complications such as hypoxia, hyper- or hypo-capnia, or hypertension (Bauer, 2012). Consequently, therapists should determine if intubation took place in pre-emergency settings because complications like hypoxia can exacerbate cognitive deficits and early intubation predicts better outcomes.

Once in the emergency room, quick and correct diagnosis of TBI is essential. Trauma nurses and physicians receive specific TBI training (Appleby, 2008). The nursing literature emphasizes that training should include diagnostic criteria, treatment instructions, and symptom management at discharge from the ER (Bay & Strong, 2011; Bergman & Bay, 2010). For example, it is easy to overlook pupillary changes that may indicate subdural bleeding, which can be fatal. Other abnormal pupillary responses should be noted because they can indicate a range of abnormal brain function (Adoni & McNett, 2007). Once a TBI diagnosis is established, a range of interventions that may be necessary: craniotomies, craniectomies or surgical evacuations (Y. J. Kim, 2011), therapeutic hypothermia (Dietrich & Bramlett, 2010; McIntyre, Fergusson, Hebert, Moher, & Hutchison, 2003; Wright, 2005), administration of statins (Rosenfeld et al., 2012), tranexamic acid, nimodipine (Lei, Gao, & Jiang, 2012), erythropoietin (Rosenfeld, et al., 2012), and progesterone (Lei, et al., 2012). In the past, interventions had the primary goal of preventing death. Now, providers consider a patient's long-term prognosis (Livingston, Tripp, Biggs, & Lavery, 2009). Interventions are used when they can facilitate *both* survival and meaningful holistic recovery. This has significant implications for rehabilitation therapists, as they will now treat patients with less severe injuries who possess greater potential for recovery.

Cognitive Assessment

Once stabilized, a therapy team evaluates and treats patients with TBI in acute care settings. When available, neuropsychologists conduct thorough initial cognitive evaluations to clearly identify impaired domains. These assessments provide objective normed data that is essential for monitoring change over time. However these assessments do not always relate to the 'real-world' functioning potential of patients as these tests may not have strong ecological validity (Gordon, 2011). Speech and language pathologists (SLP) and occupational therapists (OT) assess cognitive functioning more specifically tailored to real-world function. These specialists prefer more ecologically valid assessments including: the

Multiple Errands Test (MET), to test cognitive functioning in community settings (Alderman, Burgess, Knight, & Henman, 2003), the Assessment of Motor and Process Skills (AMPS), to test daily life skills (Merritt & Fisher, 2003), and the Canadian Occupational Performance Measure (COPM) for assessing self care, productivity (i.e. work), and leisure (McColl et al., 2005). These assessment tools can be invaluable in rehabilitation settings as they are designed to pinpoint deficit areas that affect functional performance in daily living. Therapeutic interventions continue until patients' gains plateau.

Research in cognitive neuroscience remains underutilized for cognitive rehabilitation. Neuroscientists seek to understand brain structure-function relationships, often in patient populations. In the TBI literature, these contributions are often diagnostic or prognostic in nature. For example, magnetic resonance imaging (MRI) can be used to predict functional outcomes (Moen et al., 2012). Moen and colleagues used MRI to objectively classify the degree of traumatic axonal injury (TAI) and repair over time becoming invisible to MRI. They found that early (injury – 3 months post-injury) MRI of TAI associated with TBI predicted the patient's cognitive outcome (Moen, et al., 2012). A second outcome consideration involves where the TBI damage is apparent. For instance, bilateral brain stem lesions are associated with poor long-term outcomes. Early MRI is strongly recommended to maximize their predictive power and accurately predict a patient's long-term prognosis. This can help therapists create realistic expectations for rehabilitative outcomes, and alternatively, encourage others who to achieve maximal functionality.

Research in cognitive neuroscience is also able to identify new rehabilitation targets. For example, Hartings and colleagues recorded from patients' neurons using electrocorticography and examined spreading mass neuronal depolarizations post-TBI (Hartings et al., 2011). They found that cortical spreading depolarizations corresponded to worse cognitive outcomes. This means that some available tools could be used for diagnosis and to test the efficacy of interventions. For instance, electrocorticography could be monitored acutely and subsequently by electroencephalography to monitor changes in activations pre- and post- interventions. This would be accelerated by with regular interaction between research and clinical fields.

Cognitive Rehabilitation: Remediation Approaches

Typically, in early stages of recovery remediation approaches are used, with a shift toward compensation approaches during later stages of recovery. The goal of remediation is to restore function following the view that early intervention is essential to achieve maximal rehabilitation. Greater improvement occurs within the first 5 months of recovery when compared to the subsequent 7 months (Christensen et al., 2008). However, significant gains in motor and visual spatial areas can happen beyond the initial window. Importantly, motor and visual spatial therapy should be remedial in nature for significantly longer than therapy that targets other domains. This recommendation modifies current practice, where therapists use remediation approaches in the acute stages (<5 months) of rehabilitation and shift to compensatory strategies in the later stages. It is clear that extending the use of remediation strategies may be advantageous in some recovery domains. The following sections describe existing and emerging interventions to improve cognitive outcomes.

Self-Awareness

TBI survivors often have deficits in self-awareness and subjective well-being; they are often unaware of their acquired deficits. Impaired self-awareness reduces the motivation to participate in the rehabilitation activities – as they are deemed unnecessary - and this imposes significant challenges for recovery (Bivona et al., 2013; Carroll & Coetzer, 2011; Evans, Sherer, Nick, Nakase-Richardson, & Yablon, 2005; Kelley et al., 2012; Spikman et al., 2013). Improving self-awareness is essential for improving other cognitive domains, as patients need to recognize their deficits in order to improve them. A combination of video and verbal feedback can improve self-awareness in patients without increasing emotional distress (Schmidt, Fleming, Ownsworth, & Lannin, 2013). The TBI literature relating to emotional state focuses on identifying deficits in self-awareness after TBI, rather than identifying treatment strategies. Nevertheless, researchers have found that the combined use of video and verbal feedback is one evidence-based treatment that can be used to improve self-awareness in patients with TBI.

Learning and Memory

Individuals with TBI have difficulty with learning and memory due to encoding deficits (Goverover, Arango-Lasprilla, Hillary, Chiaravalloti, & Deluca, 2009). Here, classic memory research may be beneficial. Strategies that promote deeper encoding, and slow information presentation facilitate learning in healthy individuals. One deep encoding technique, self-generation, asks individuals to create their own examples to better understand new material. Spacing out information is a technique where small amounts of new information are presented in multiple short time periods. Researchers applied both of these strategies in individuals who had sustained a TBI. In this population spacing out information over a longer amount of time (Goverover, et al., 2009) and self-generation of responses facilitated recall (Goverover, Chiaravalloti, & DeLuca, 2010). Another study used the concept of *testing* as a remediation approach for learning and memory because it improves memory performance in healthy adults (Roediger & Karpicke, 2006). Testing helped to facilitate gains in both learning and memory in survivors of severe TBI (Pastotter, Weber, & Bauml, 2013). In summary, OTs should encourage individuals with TBI to use established memory encoding strategies, like self-generation and testing, to enhance encoding and retention of information.

Individuals with TBI also have deficits in prospective memory, the ability to remember to perform activities in the future. For example, remembering to take the trash to the curb every Monday. Researchers investigated why individuals with TBI have difficulty with prospective memory. Again, encoding difficulties combined with deficits in self-awareness may make them less likely to use external memory aids (Roche, Moody, Szabo, Fleming, & Shum, 2007). Individuals with TBI benefit from applying strategies associated with the use visual imagery to assist with prospective memory. The intervention used graded complexity in naturalistic settings and improved prospective memory by strengthening the memory trace and facilitating recall of the intended action (Potvin, Rouleau, Senechal, & Giguere, 2011). Visual imagery is a useful tool for improving prospective memory following TBI.

Executive Function

Executive functioning (EF) is the ability to plan, organize, strategize, and focus attention. Deficits in EF following TBI can be profound and debilitating. The *cognitive orientation to occupational performance* model (CO-OP) encourages individuals who have sustained a TBI to use metacognitive strategies to identify and strengthen weak areas of cognition. Metacognition refers to the ability to recognize one's cognitive capacity. If a patient recognized, for example, that he had trouble remembering verbally presented information, he could use a metacognitive strategy of requesting written information (D.R. Dawson et al., 2009). Telerehabilitation, such as videoconferencing between patients and therapists, can also support this approach (Ng, Polatajko, Marziali, Hunt, & Dawson, 2013). An ecologically valid intervention includes using virtual environments to target EF deficits. For example, Jacoby and colleagues used a virtual supermarket to successfully train executive functioning in adults with TBI (Jacoby et al., 2013). Deficits in EF are also managed with compensatory strategies to improve daily activity performance. These compensatory strategies are described in more detail in a later section. The remediation approaches for improving EF include: using metacognitive strategies, providing videoconference support to patients, and adopting virtual reality environments to prepare for community reintegration.

Attention

Attentional deficits are common after TBI and exist in realms of selective, sustained, and divided attention. Attention Process Training (APT) is shown to improve selective attention in individuals with TBI by progressively increasing attentional demands (Pero, Incoccia, Caracciolo, Zoccolotti, & Formisano, 2006). Recent work in patients with severe TBI has found success using tactile feedback in a virtual environment to facilitate recovery of sustained attention on visuo-motor tasks (Dvorkin et al., 2013). Training in divided attention tasks can improve performance on them, but this improvement does not transfer to other cognitive tasks (e.g. executive functioning) (Couillet et al., 2010). Clinicians have found that attention process training, providing tactile feedback, and training divided attention can successfully ameliorate attention deficits.

Other experimental techniques, including neurostimulation and neuroimaging hold promise. For instance, transcranial direct current stimulation (tDCS) applied to the left prefrontal cortex can improve performance of attention tasks for individuals with TBI (Kang, Kim, & Paik, 2012). Functional magnetic resonance imaging (fMRI) findings are clarifying the neural mechanism associated with attentional training (Y. H. Kim et al., 2009). In this study, all participants completed a visuospatial attention task in conjunction with fMRI. In comparison to healthy controls, participants with TBI demonstrated greater regions of frontal and temporoparietal lobe activity along with reduced evidence of activity in the anterior cingulate gyrus, supplementary motor area, and temporal occipital regions. Following the intervention, individuals with TBI demonstrated behavioral improvement, and more normal cortical patterns of activity. These results support the concept that rehabilitation progress is made due to neural plasticity. While fMRI cannot feasibly be used to identify maladaptive cortical patterns in individual patients, it can be used to identify which types of rehabilitative interventions promote more typical patterns of cortical activity.

Scientists have found that neurostimulation can improve attentional capacity and fMRI may be a viable tool to objectively measure cortical changes after therapeutic intervention.

Daily Cognition

In addition to targeting specific cognitive domains, rehabilitation research examines ways to improve overall cognitive function, or daily cognition. One daily cognitive activity that is difficult for individuals with TBI is using technology – including electronic, technical and mechanical equipment (Engstrom, Lexell, & Lund, 2010). Rehabilitation professionals must address these difficulties with interventions that promote successful technology use. TBI literature supports the idea that re-learning of daily tasks in a natural setting leads to greater functional gains, particularly for patients with cognitive deficits (D.R. Dawson, et al., 2009). It is often in a naturalistic setting that a patient's functional potential becomes apparent. There is emerging data showing that transfer effects is possible between technology and the real world. Randomized computer based practice for about an hour per day for 13 days facilitated transfer effects to everyday skills in adult men with TBI (Giuffrida, Demery, Reyes, Lebowitz, & Hanlon, 2009). In summary, daily cognition can be improved by providing therapy in patient's natural environment and through use of technology to train skills needed for daily functioning.

The paragraphs above outline empirically based interventions to remediate cognitive deficits following a TBI. As stated earlier, some of these interventions are not yet available for clinical use as they are in the research and development stages. Nevertheless, clinicians should be aware of developing remedial approaches, as many are likely to reach clinical settings in the future.

Cognitive Rehabilitation: Compensation Approaches

With time even the best remedial approaches fail to promote functional gains and rehabilitation turns to compensatory approaches. The goal of compensation approaches is to find ways to offset degrees of impaired functioning. Difficulties performing daily activities can arise from deficits in any of the cognitive domains listed above. Therefore, most compensatory strategies attempt to facilitate improvements in daily activities without specifically targeting a cognitive domain. Typically, compensatory strategies involve the use of assistive technology (AT). AT can improve daily task performance in adults who have sustained a TBI and, with training and education, health professionals become more receptive to use of AT (de Joode, van Boxtel, Verhey, & van Heugten, 2012). Boman and colleagues conducted a study that used a training apartment to determine where patients would likely have memory lapses upon discharge from a rehabilitation setting. A computer registered the number of times they forgot to complete a predefined set of activities. Patients made the greatest number of errors when using the refrigerator and the stove. Following this assessment, all participants received training using electronic memory aids and collectively demonstrated improvement in their ability to use the aids to complete daily tasks. Determining which electronic aids will be useful can be facilitated by use of a training apartment (Boman, Lindberg Stenvall, Hemmingsson, & Bartfai, 2010). Health insurance reimbursement for AT is limited making widespread use less likely, even though it is an evidenced based way of improving daily functioning. Health insurance reimbursement for

AT could be improved with more research supporting the successful use of AT in clinical populations and subsequent political campaigning for reimbursement of this technology.
Improving access

Overcoming Barriers to Progress

Cognitive disabilities after TBI are assessed and treated by teams of clinicians using the best information they have. In general, scientists seek to understand the basic science surrounding TBI. To expedite translational success better communication between various disciplines would likely improve cognitive outcomes for people with TBI. The interdisciplinary nature of TBI means that different groups are targeting different problems using different techniques, and publishing in field-relevant journals, making communication across disciplines a real challenge.

There is a clear need for more research in cognitive rehabilitation for the everyday citizen who has sustained a TBI. Indeed since 2006 only around 20 empirical articles addressed remedial or compensatory approaches in this population (Boman, et al., 2010; Couillet, et al., 2010; D. R. Dawson et al., 2009; de Joode, et al., 2012; Dvorkin, et al., 2013; Engstrom, et al., 2010; Giuffrida, et al., 2009; Goverover, et al., 2009; Goverover, et al., 2010; Jacoby, et al., 2013; Kang, et al., 2012; Y. H. Kim, et al., 2009; Ng, et al., 2013; Pastotter, et al., 2013; Pero, et al., 2006; Potvin, et al., 2011; Roche, et al., 2007; Roediger & Karpicke, 2006; Schmidt, et al., 2013). Increasing the amount of interdisciplinary work and enhancing access to these findings is essential and could create the 'gold standard' for cognitive rehabilitation. This would improve clinicians' abilities to select and tailor an evidence-based cognitive rehabilitation program for their patient in a time efficient and effective manner. In seeking ways to promote interdisciplinary work, we spoke to both OTs and researchers to gather anecdotal information about their experiences with interdisciplinary work. The following barriers to effective interdisciplinary work were raised. OTs indicated limited access to empirical work and difficulty understanding researchers using discipline specific jargon; see Table 1. Researchers indicated reduced awareness of clinical needs and problems. These potential solutions could provide a starting point for conversations between groups engaged in TBI research and treatment. A second aim would be to refine and target translational researchers to address clinical needs more carefully.

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Table 1

Summary of Empirical Articles for Each Cognitive Domain

Domain and # of Articles	Citations
Self Awareness (3)	Goverover, Johnston, Toglia, & Deluca, 2007; Lundqvist, Linnros, Orlenius, & Samuelsson, 2010; Schmidt, Fleming, Ownsworth, & Lannin, 2013
Learning and Memory (12)	Bougeois, Lenius, Turkstra, & Camp, 2007; Fish et al., 2007; Goverover, Arango-Lasprilla, Hillary, Chiaravalloti, & Deluca, 2009; Goverover, Chiaravalloti, & Deluca, 2010; Grilli & Glisky, 2011; Grilli & McFarland, 2011; O'Brien, Chiaravalloti, Arango-Lasprilla, Lengenfelder, & DeLuca, 2007; Pastotter, Weber, & Bauml, 2013; Potvin, Rouleau, Senechal, & Giguere, 2011; Roediger & Karpicke, 2006; Sumowski, Coyne, Cohen, & Deluca, 2014; Yip & Man, 2013
Executive Function (7)	Bertens, Fasotti, Boelen, & Kessels, 2013; Dawson, Binns, Hunt, Lemsky, & Polatajko, 2013; Dawson et al., 2009; Hewitt, Evans, & Dritschel, 2006; Jacoby et al., 2013; Ng, Polatajko, Marziali, Hunt, & Dawson, 2013; Serino et al., 2007
Attention (4)	Bartfai, Markovic, Sargenius Landahl, & Schult, 2014; Couillet et al., 2010; Dvorkin et al., 2013; Pero, Incocchia, Caracciolo, Zoccolotti, & Formisano, 2006
Generalized Strategies & Approaches (3)	Hegde, 2014; Lojovich, 2010; McDonnell, Smith, & Mackintosh, 2011
Daily Cognition (7)	Engstrom, Lexell, & Lund, 2010; Fong et al., 2010; Giuffrida, Demery, Reyes, Lebowitz, & Hanlon, 2009; Johansson & Tormalm, 2012; Kim, 2010; Lundqvist, Grundstrom, Samuelsson, & Romberg, 2010; Powell, Letson, Davidoff, Valentine, & Greenwood, 2008
Compensatory Strategies (7)	Boman, Lindberg Stenvall, Hemmingsson, & Bartfai, 2010; Boman, Tham, Grandqvist, Bartfai, & Hemmingsson, 2007; de Joode, van Boxtel, Verhey, & van Heugten, 2012; Dry, Colantonio, Cameron, & Mihailidis, 2006; Fager, Hux, Beukelman, & Karantounis, 2006; Fried-Oken, Beukelman, & Hux, 2011; Gentry, Wallace, Kvarfordt, & Lynch, 2008