ERABI
EVIDENCE-BASED REVIEW
of moderate to severe
ACQUIRED BRAIN INJURY

REHABILITATION OF PROBLEM SOLVING, EXECUTIVE & GENERAL COGNITIVE FUNCTIONING

POST ACQUIRED BRAIN INJURY

Cecilia Flores-Sandoval PhD, Shawn Marshall MD FRCPC, Shannon Janzen MSc, Penny Welch-West M.Cl.Sc. SLP, Amber Harnett MSc RN, Connie Ferri MSc SLP, Robert Teasell MD FRCPC

Disclaimer

This review has been prepared based on the scientific and professional information available up to July 2021. The ERABI information is provided for informational and educational purposes only. If you have or suspect you have a health problem, you should consult your health care provider. The ERABI contributors shall not be liable for any damages, claims, liabilities, costs, or obligations arising from the use or misuse of this material.

Copyright

Funding

This work is supported by the Ontario Ministry of Health. All work produced by ERABI is editorially independent from its funding source.

Conflict of Interest

In the context of ERABI development, the term “conflict of interest” (COI) refers to situations in which an author or ERABI staff member’s financial, professional, intellectual, personal, organizational or other relationships may compromise their ability to independently conduct this evidence-based review. No limiting conflicts were identified.

Contact Information

Evidence-Based Review of Moderate to Severe Acquired Brain Injury

550 Wellington Rd South, London, Ontario, Canada N6C 0A7

Website: www.ERABI.ca

Greetings from Dr. Robert Teasell,

Professor and Chair-Chief of Physical Medicine and Rehabilitation

The Collaboration of Rehabilitation Research Evidence (CORRE) team is delighted to present the Evidence-Based Review of moderate to severe Acquired Brain Injury (ERABI) *Rehabilitation of Problem Solving, Executive & General Cognitive Functioning Post Acquired Brain Injury.* Through collaboration of researchers, clinicians, administrators, and funding agencies, ERABI provides an up-to-date review of the current evidence in brain injury rehabilitation. ERABI synthesizes the research literature into a utilizable format, laying the foundation for effective knowledge transfer to improve healthcare programs and services.

We offer our heartfelt thanks to the many stakeholders who are able to make our vision a reality. Firstly, we would like to thank the Ontario Ministry of Health, which recognizes ERABI's capacity to lead in the field of brain injury evidence-based reviews and is committed to funding it. We would also like to thank the co-chairs of ERABI, Dr. Mark Bayley (University of Toronto) and Dr. Shawn Marshall (University of Ottawa) for their invaluable expertise and stewardship of this review. Special thanks to the authors for generously providing their time, knowledge and perspectives to deliver a rigorous and robust review that will guide research, education and practice for a variety of healthcare professionals. We couldn't have done it without you! Together, we are building a culture of evidence-based practice that benefits everyone.

We invite you to share this evidence-based review with your colleagues, patient advisors that are partnering within organizations, and with the government agencies with which you work. We have much to learn from one another. Together, we must ensure that patients with brain injuries receive the best possible care every time they require rehabilitative care – making them the real winners of this great effort!

Robert Teasell, MD FRCPC

TABLE OF CONTENTS

Preface

About the Authors

ERABI is internationally recognized and led by a team of clinicians and researchers with the goal of improving patient outcomes through research evidence. Each ERABI module is developed through the collaboration of many healthcare professionals and researchers.

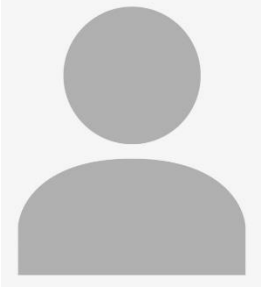
Cecilia Flores-Sandoval, PhD, is a clinical research assistant and the coordinator of the Evidence-Based Review of Acquired Brain Injury (ERABI). She completed a master's degree and a PhD in Health and Rehabilitation Sciences, field of Health and Aging. Her research interests include aging and rehabilitation, patient engagement and transitional care for older adults.

Dr. Shawn Marshall is a physician specializing in Physical Medicine and Rehabilitation (Physiatrist). He is the Division Head of Physical Medicine and Rehabilitation at the University of Ottawa and The Ottawa Hospital where he manages both in-patients and out-patient clinics for patients with concussion to severe traumatic brain injury. Dr. Marshall has a Master's degree in Clinical Epidemiology and is a Full Professor at the University of Ottawa in the Department of Medicine.

Shannon Janzen, MSc, is a research associate and the project coordinator for the Evidence-Based Review of Acquired Brain Injury (ERABI). Her research interests focus on the integration of best evidence into clinical practice to optimize patient outcomes, with an emphasis on knowledge translation initiatives.

Penny Welch-West has been working as a Speech-Language Pathologist since 1998 and enjoys a very varied practice ranging from Rehabilitation through Complex/Continuing and Palliative Care. This work includes teaching, assessment and treatment in the areas of dysphagia (swallowing), voice, articulation, language, cognitive-communication and Augmentative and Alternative Communication (AAC).

Amber Harnett, MSc, RN, CNF scholar, completed her MSc in pathology and the accelerated BScN program at Western University. Passionate about supporting and advocating for those with acquired brain injuries, she works as a research coordinator to improve healthcare systems through research synthesis, guidelines development, knowledge translation, education, and outreach, in the CORRE lab at Parkwood Institute.



Connie Ferri is a speech-language pathologist at Parkwood Institute.

Dr. Robert Teasell is Professor of Physical Medicine and Rehabilitation, Schulich School of Medicine and Dentistry, Western University and a Clinical Researcher at Lawson Research Institute in London, Ontario. He is a clinician at Parkwood Institute, St. Joseph's Health Care London.

Purpose

The Evidence-Based Review of Acquired Brain Injury (ERABI) is a systematic review of the rehabilitation literature of moderate to severe acquired brain injuries (ABI). It is an annually updated, freely accessible online resource that provides level of evidence statements regarding the strength of various rehabilitation interventions based on research studies. The ERABI is a collaboration of researchers in London, Toronto and Ottawa. Our mission is to improve outcomes and efficiencies of the rehabilitation system through research synthesis, as well as from providing the foundational research evidence for guideline development, knowledge translation, and education initiatives to maximize the real-world applications of rehabilitation research evidence.

Key Concepts

Acquired Brain Injury

For the purposes of this evidence-based review, we used the definition of ABI employed by the Toronto Acquired Brain Injury Network (2005). ABI is defined as damage to the brain that occurs after birth and is not related to congenital disorders, developmental disabilities, or processes that progressively damage the brain. ABI is an umbrella term that encompasses traumatic and non-traumatic etiologies.

TABLE 1 | Defining Acquired Brain Injury

Included in ABI definition	Excluded from ABI definition
Traumatic Causes • Motor vehicle accidents • Falls • Assaults • Gunshot wounds • Sport Injuries **Non-traumatic Causes** • Tumours (benign/meningioma only) • Anoxia • Subarachnoid hemorrhage (non-focal) • Meningitis • Encephalitis/encephalopathy (viral, bacterial, drug, hepatic) • Subdural Hematoma	**Vascular and Pathological Incidents** • Intracerebral hemorrhage (focal) • Cerebrovascular accident (i.e., stroke) • Vascular accidents • Malignant/metastatic tumours **Congenital and Developmental Problems** • Cerebral Palsy • Autism • Developmental delay • Down's syndrome • Spina bifida with hydrocephalus **Progressive Processes** • Alzheimer's disease • Pick's disease • Dementia • Amyotrophic Lateral Sclerosis • Multiple Sclerosis • Parkinson's disease • Huntington's disease

Given that 'ABI' can have multiple definitions, studies with an 'ABI' population can be equally heterogeneous in terms of the sample composition. Such studies may include any combination of persons with TBI, diffuse cerebrovascular events (i.e., subarachnoid hemorrhage) or diffuse infectious disorders (i.e., encephalitis or meningitis). The vast majority of individuals with ABI have a traumatic etiology; therefore, much of the brain injury literature is specific to TBI. The terms ABI and TBI have been used intentionally throughout ERABI to provide more information about populations where relevant.

Moderate to Severe Brain Injury

ABI severity is usually classified according to the level of altered consciousness experienced by the patient following injury (Table 2). The use of level of consciousness as a measurement arose because the primary outcome to understand the severity of an injury is the Glasgow Coma Scale. Consciousness levels following ABI can range from transient disorientation to deep coma. Patients are classified as having a mild, moderate or severe ABI according to their level of consciousness at the time of initial assessment. Various measures of altered consciousness are used in practice to determine injury severity. Common measures include the Glasgow Coma Scale (GCS), the duration of loss of consciousness (LOC), and the duration of post-traumatic amnesia (PTA). Another factor used to distinguish moderate and severe brain injury is evidence of intracranial injury on conventional brain imaging techniques which distinguish severity of injury from a mild or concussion related brain injury.

TABLE 2 | Defining Severity of Traumatic Brain Injury, adapted from Veterans Affairs Taskforce (2008) and Campbell (2000)

Criteria	Mild	Moderate	Severe	Very Severe
Initial GCS	13-15	9-12	3-8	Not defined
Duration LOC	< 15minutes*	<6 hours	6-48 hours	>48 hours
Duration PTA	< 1hour*	1-24 hours	1-7 days	>7 days
	*This is the upper limit for mild traumatic brain injury; the lower limit is any alteration in mental status (dazed, confused, etc.).			

Methods

An extensive literature search using multiple databases (CINAHL, PubMed/MEDLINE, Scopus, EMBASE, and PsycINFO) was conducted for articles published in the English language between 1980–July 2021 that evaluate the effectiveness of any intervention/treatment related to ABI. The references from key review articles, meta-analyses, and systematic reviews were reviewed to ensure no articles had been overlooked. For certain modules that lacked research evidence the gray literature, as well as additional databases, were searched in order to ensure the topic was covered as comprehensively as possible.

Specific subject headings related to ABI were used as the search terms for each database. The search was broadened by using each specific database's subject headings, this allowed for all other terms in the database's subject heading hierarchy related to ABI to also be included. The consistent search terms used were "head injur*", "brain injur*", and "traumatic brain injur*". Additional keywords were used specific to each module. A medical staff librarian was consulted to ensure the searches were as comprehensive as possible.

Every effort was made to identify all relevant articles that evaluated rehabilitation interventions/ treatments, with no restrictions as to the stage of recovery or the outcome assessed. For each module, the individual database searches were pooled, and all duplicate references were removed. Each article title/abstract was then reviewed; titles that appeared to involve ABI and a treatment/intervention were selected. The remaining articles were reviewed in full.

Studies meeting the following criteria were included: (1) published in the English language, (2) at least 50% of the study population included participants with ABI (as defined in Table 1) or the study independently reported on a subset of participants with ABI, (3) at least three participants, (4) ≥50% participants had a moderate to severe brain injury (as defined in Table 2), and (5) involved the evaluation of a treatment/intervention with a measurable outcome. Both prospective and retrospective studies were considered. Articles that did not meet our definition of ABI were excluded.

Interpretation of the Evidence

The levels of evidence (Table 3) used to summarize the findings are based on the levels of evidence developed by Sackett et al. (2000). The levels proposed by Sackett et al. (2000) have been modified; specifically, the original ten categories have been reduced to five levels. Level 1 evidence pertains to high quality randomized controlled trials (RCTs) (PEDro ≥6) and has been divided into two subcategories, level 1a and level 1b, based on whether there was one, or more than one, RCT supporting the evidence statement.

The evidence statements made in evidence-based reviews are based on the treatment of groups rather than individuals. There are times when the evidence will not apply to a specific case; however, the majority of patients should be managed according to the evidence. Ultimately, the healthcare professional providing care should determine whether an intervention is appropriate and the intensity with which it should be provided, based on their individual patient's needs. Furthermore, readers are asked to interpret the findings of studies with caution as evidence can be misinterpreted. The most common scenario occurs when results of a trial are generalized to a wider group than the evidence allows. Evidence is a tool, and as such, the interpretation and implementation of it must always be done with the known limitations in mind.

TABLE 3 | Levels of Evidence

Level	Research Design	Description
1A	Randomized Controlled Trial (RCT)	More than one RCT with PEDro score ≥6. Includes within subject comparisons, with randomized conditions and crossover designs
1B	RCT	One RCT with PEDro ≥6
2	RCT	One RCT with PEDro <6
	Prospective Controlled Trial (PCT)	Prospective controlled trial (not randomized)
	Cohort	Prospective longitudinal study using at least two similar groups with one exposed to a particular condition
3	Case Control	A retrospective study comparing conditions including historical controls
4	Pre-Post Trial	A prospective trial with a baseline measure, intervention, and a post-test using a single group of subjects
	Post-test	A prospective intervention study using a post intervention measure only (no pre-test or baseline measurement) with one or more groups
	Case Series	A retrospective study usually collecting variables from a chart review
5	Observational study	Using cross sectional analysis to interpret relations
	Clinical Consensus	Expert opinion without explicit critical appraisal, or based on physiology, biomechanics or “first principles”
	Case Reports	Pre-post or case series involving one subject

Strength of the Evidence

The methodological quality of each randomized controlled trial (RCT) was assessed using the Physiotherapy Evidence Database (PEDro) rating scale developed by the Centre for Evidence-Based Physiotherapy in Australia (Moseley et al., 2002). The PEDro is an 11-item scale; a point is awarded for ten satisfied criterion yielding a score out of ten. The first criterion relates to external validity, with the remaining ten items relating to the internal validity of the clinical trial. The first criterion, eligibility criteria, is not included in the final score. A higher score is representative of a study with higher methodological quality.

REHABILITATION OF PROBLEM SOLVING, EXECUTIVE AND GENERAL COGNITIVE FUNCTIONING

POST ACQUIRED BRAIN INJURY

Summary of the Evidence

Intervention	Key Point Level of Evidence
Rehabilitation of Executive Functioning	
Non-Pharmacological Interventions	
Biofeedback	Heart rate variability biofeedback may improve executive functions; however, more controlled studies are required to make further conclusions. - *There is level 4 evidence that heart rate biofeedback may improve executive functioning following an ABI, although higher level studies are required to fully determine this (Kim et al., 2018).*
Dual-Task Training	Dual-task training may not improve executive function in individuals with TBI. - *There is level 2 evidence that dual-task training may not improve executive functioning in individuals with TBI (Couillet et al., 2010).*
Hypnosis	Targeted hypnosis may improve working memory and executive function in individuals with ABI. - *There is level 1b evidence that targeted hypnosis may improve executive function in individuals with ABI (Lindeløv, Overgaard, & Overgaard, 2017).*
General Cognitive Rehabilitation Programs	The SMART program may be effective for improving executive functioning following an ABI. A cognitive pragmatic treatment (CPT) program may improve communicative-pragmatic abilities, including executive function, in individuals with severe TBI. A comprehensive cognitive strategy that addresses problems of daily living may improve executive functioning in daily life in individuals with ABI. Categorization training may improve executive function in individuals with TBI. Attention Process Training likely improves performance in executive functioning. An explicit problem-solving skills training program using a metacomponential approach may not be effective at improving execute e function. - *There is level 1b evidence that the Strategic Memory and Reasoning Training (SMART) program is more effective than a brain health workshop for improving executive function, metacognition, and comprehension following ABI (Vas, Chapman, Cook, Elliott, & Keebler, 2011).* - *There is level 4 evidence that a cognitive pragmatic treatment (CPT) program may improve communicative-pragmatic abilities, including cognitive components such as awareness and executive functions, in individuals with severe TBI (Gabbatore et al., 2015).*

	- *There is level 1b evidence that a comprehensive cognitive strategy that addresses problems of daily living may improve executive functioning in daily life in individuals with ABI (Spikman, Boelen, Lamberts, Brouwer, & Fasotti, 2010).* - *There is level 2 evidence that an explicit problem-solving skills training program using a metacomponential approach may be effective at improving metacomponential functioning but this improvements were not translated to real-life situations for individuals with ABI (Fong & Howie, 2009).* - *There is level 1b evidence that Categorization training may improve cognitive functioning, including executive function, in individuals with TBI (Constantinidou, Thomas, & Robinson, 2008).* - *There is level 1b evidence that Attention Process Training (APT) may be improve performance in tasks that required executive function (Sohlberg, McLaughlin, Pavese, Heidrich, & Posner, 2000).* - *There is level 2 evidence that the Intensive NeuroRehabilitation programme, compared to no treatment, does not improve executive functioning in individuals with ABI (Holleman, Vink, Nijland, & Schmand, 2018).*
Goal Management Training	Goal Management Training may improve executive function in individuals with TBI; however, this intervention may not be effective when combined with mobile technology. - *There is level 1b evidence that Goal Management Training (GMT), may be effective for the remediation of executive functioning in individuals with ABI (Levine et al., 2000; Tornas et al., 2016; Tornas, Lovstad, Solbakk, Schanke, & Stubberud, 2019).* - *There is level 1b evidence that Goal Management Training (GMT) combined with the use of mobile technology may not be effective in improving executive function in individuals with ABI (Elbogen et al., 2019; Gracey et al., 2017).* Goal-directed attentional self-regulation training may improve executive function in individuals with ABI. - *There is level 2 evidence that goal-directed attentional self-regulation training may improve executive function in individuals with ABI (A. J. Chen et al., 2011; Cizman Staba, Vrhovac, Mlinaric Lesnik, & Novakovic-Agopian, 2020; Novakovic-Agopian et al., 2011).*
Music Therapy	Music therapy may enhance executive function in individuals with TBI. - *There is level 1b evidence music therapy may improve executive function in individuals with TBI (Noelia Martinez-Molina et al., 2021; Siponkoski et al., 2021; Siponkoski et al., 2020).*
Dance Therapy	Dance therapy may improve executive function in individuals with TBI. - *There is level 1b evidence that a dance program is feasible and may improve executive function in individuals with severe TBI (Sarkamo et al., 2021).*
Computer-Based Interventions	Computer assisted rehabilitation and computer software programs (BrainHQ, ProSolv) may not be effective at improving executive function in patients post TBI. - *There is level 2 evidence that computer assisted cognitive rehabilitation and computer software programs, such as BrainHQ and ProSolv, may not be effective at improving executive function in individuals post TBI (S. H. Chen, Thomas, Glueckauf, & Bracy, 1997; O'Neil-Pirozzi & Hsu, 2016; L. E. Powell et al., 2019).*
Virtual Reality	Virtual reality does not likely improve executive functioning following an ABI.

	- *There is level 1b evidence that virtual-reality training is not superior to conventional cognitive training at improving executive function outcomes post TBI (Dahdah et al., 2017; Jacoby et al., 2013; Man, Poon, & Lam, 2013).*
Mobile Technology	A Cognitive Application for Life Management (CALM) intervention may not be effective in treating executive dysfunction in individuals post TBI. The ProSolv mobile application may not improve executive function in individuals with ABI. Combining a brief goal-directed rehabilitation with SMS text message alerts may not improve executive function in individuals with ABI. - *There is level 1b evidence that a Cognitive Application for Life Management (CALM) intervention, that involves both goal management training (GMT) and the use of mobile devices may not be effective in treating executive dysfunction in individuals with TBI (Elbogen et al., 2019).* - *There is level 2 evidence that the ProSolv mobile application may not improve executive functioning in individuals with ABI (L. E. Powell et al., 2019).* - *There is level 1b evidence that pairing a brief-goal directed rehabilitation with SMS text messages may not be effective in enhancing executive function in individuals with ABI (Gracey et al., 2017).*
Repetitive Transcranial Magnetic Stimulation	rTMS may not improve executive function in individuals with TBI. More studies are needed to further explore the effectiveness of this brain stimulation technique. - *There is level 1b evidence that rTMS may not enhance executive functioning in individuals with TBI (Neville et al., 2019).*
Emotional Regulation	Emotional regulation interventions may improve executive function in individuals with TBI. - *There is level 1b evidence that emotional regulation interventions are effective at improving executive function in individuals with TBI (Cantor et al., 2014; Rath, Simon, Langenbahn, Sherr, & Diller, 2003).*
Pharmacological Interventions	
Donepezil	Donepezil may improve executive function in individuals with TBI. - *There is level 4 evidence that donepezil is effective in improving executive function in individuals post TBI (Khateb, Ammann, Annoni, & Diserens, 2005).*
Methylphenidate	Methylphenidate likely does not improve executive function in individuals with TBI. - *There is level 1a evidence that methylphenidate may not be effective, compared to placebo for the improvement of executive functioning following TBI (Al-Adawi et al., 2020; Dymowski et al., 2017; P. O. Jenkins et al., 2019; Speech, Rao, Osmon, & Sperry, 1993).*
Sertraline	Sertraline may not improve executive function and may be associated with several side effects. - *There is level 1b evidence that sertraline does not improve executive function, compared to placebo, in individuals who have sustained a moderate to severe TBI*

	(Banos et al., 2010).
Amantadine	The evidence on the effectiveness of Amantadine in improving function is unclear, more studies are needed. - *There is level 1b evidence that Amantadine may not help to improve executive functioning in individuals with TBI compared to placebo (Schneider, Drew-Cates, Wong, & Dombovy, 1999); however, more studies are needed.*
Bromocriptine	Bromocriptine may improve executive function in individuals with TBI. However, additional studies are needed to fully determine the effectiveness of this treatment. - *There is level 2 evidence that bromocriptine may improve executive function in individuals with TBI (McDowell, Whyte, & D'Esposito, 1998; J. H. Powell, al-Adawi, Morgan, & Greenwood, 1996).*
Growth Hormone Replacement Therapy	The effectiveness of rhGH in improving executive functioning in individuals with TBI is unclear. More studies are needed to determine the benefits of this treatment for executive function. - *There is conflicting (level 1b and level 2) evidence regarding the effectiveness of rhGH in improving executive functioning post TBI (High et al., 2010; Moreau et al., 2013).*
Rivastigmine	Rivastigmine is not effective in remediating executive dysfunction post ABI. - *There is level 1b evidence that rivastigmine is not effective for improving executive functioning, compared to placebo, following an ABI (Silver et al., 2006; Silver et al., 2009).*
Hyperbaric Oxygen Therapy	Hyperbaric oxygen therapy may be beneficial for improving executive function following an ABI; however, more research is needed. - *There is level 4 evidence that hyperbaric oxygen therapy may improve executive function following an ABI (Hadanny, Abbott, Suzin, Bechor, & Efrati, 2018).*
Rehabilitation of General Cognitive Functioning	
Non-Pharmacological Interventions	
General Cognitive Rehabilitation Programs	General cognitive rehabilitation programs are effective for improving cognitive functioning following an ABI. Corrective video feedback is more effective than verbal feedback alone for improving general cognitive function and self-awareness. Remedial and adaptive occupational therapy are equally effective for improving general cognitive functioning. An in-home program, Trabajadora de Salud, may improve general cognitive functioning compared to standard therapy for Latin American individuals with an ABI. Quasi-contextualized treatment may enhance cognitive outcomes for individuals with TBI. - *There is level 1b evidence that corrective video feedback is more effective for improving generalized cognitive functioning and self-awareness compared to verbal*

	feedback only in individuals with an ABI (Schmidt, Fleming, Ownsworth, & Lannin, 2013). - *There is level 1b evidence that cognitive therapies compared to standard therapy are more effective than no therapy for improving generalized cognitive functioning, as well as self-awareness following an ABI (Goverover, Johnston, Toglia, & DeLuca, 2007).* - *There is level 1b evidence that remedial occupational therapy and adaptive occupational therapy may have equal effects on generalized cognitive function in those with an ABI (Neistadt, 1992).* - *There is level 2 evidence that an in-home program, Trabajadora de Salud, may improve general cognitive functioning compared to standard therapy for individuals with an ABI, particularly individuals from Latin America (Linton & Kim, 2018).* - *There is level 2 evidence that executive and compensatory memory retraining may be effective for general cognition in individuals with TBI (Freeman, Mittenberg, Dicowden, & Bat-Ami, 1992).* - *There is level 4 evidence that a low intensity outpatient cognitive rehabilitation program may improve goal attainment and cognitive impairment in individuals post ABI (Rasquin et al., 2010).* - *There is level 4 evidence that the use of quasi-contextualized treatment may improve cognitive outcomes in individuals with TBI (Beaulieu et al., 2021).* - *There is level 4 evidence that an intensive rehabilitation program may enhance cognitive reserve in individuals with severe TBI (D. Bertoni et al., 2020).*
Drill & Practice Training	Cognitive retraining program focused on repetitive practice and drills may improve processing speed, working memory and executive function following moderate to severe TBI. - *There is level 4 evidence that a cognitive retraining program may improve processing speed, working memory and executive function following moderate to severe TBI (Asfar et al. 2021).*
Yoga	Yoga may be an effective therapy to improve cognition in individuals with TBI. - *There is level 4 evidence that a yoga intervention may enhance general cognitive functioning in individuals with TBI (Donnelly et al., 2021).*
Computer-Based Interventions	The Parrot computer-based cognitive retraining program may improve general cognition post ABI. - *There is level 4 evidence that the Parrot computer-based cognitive retraining program may enhance general cognitive functioning in individuals with ABI (Li, Alonso, Chadha, & Pulido, 2015).*
Mindfulness	A mindfulness-based stress reduction intervention may be effective for improving cognitive functioning. However, more research is needed. - *There is level 4 evidence that mindfulness-based stress reduction intervention may be effective for improving general cognitive functioning in individuals with an ABI (Combs, Critchfield, & Soble, 2018).*
Pharmacological Interventions	
Methylphenidate	Methylphenidate may improve general cognition functioning in individuals with TBI.

	- *There is level 1b evidence that methylphenidate may improve general cognition in individuals with TBI (Zhang & Wang, 2017).*
Amantadine	Amantadine may not improve general cognition functioning in individuals with TBI. - *There is level 1b evidence that amantadine may not improve general cognition in individuals with TBI (Ghalaenovi et al., 2018).*
Growth Hormone Replacement Therapy	Growth Hormone Replacement Therapy may enhance general cognitive functioning in individuals with TBI. - *There is level 2 evidence that* rhGH administration may improve general cognitive functioning in individuals with TBI (Reimunde et al., 2011).
Dextroamphetamine	Dextroamphetamine may not improve global cognitive functioning in individuals with ABI and may increase agitation and emotional distress. - *There is level 1b evidence that dextroamphetamine does not global cognitive functioning following an ABI (Hart, Whyte, Watanabe, & Chervoneva, 2018).*

Introduction

Executive functions refer to higher-level cognitive functions that are primarily mediated by the frontal lobes. Executive functions are top-down mental processes that facilitate concentration during complex tasks, and include inhibition, interference control, working memory, and cognitive flexibility. Other related functions associated with executive function are insight, awareness, judgment, planning, organization, problem solving, multi-tasking and working memory (Lezak, 2004). Executive deficits are prevalent following traumatic brain injury (TBI), from both a pathophysiologic as well as a psychosocial perspective. The frontal lobes tend to be one of the brain areas most likely to be injured following trauma (Greenwald, Burnett, & Miller, 2003). Frequently bilateral frontal lobe injury occurs following TBI which in contrast to typically unilateral insults following vascular injury. Executive functioning may be affected when a direct contusion to the frontal and temporal lobes occurs, as well as a diffuse axonal injury. Individuals with a TBI often present with cognitive and behavioral deficits in the presence of some degree of physical impairment.

Cicerone et al. (2000) reviewed 14 studies examining executive functioning and problem-solving. Only three of the identified studies included a control group and were classified as a randomized controlled trial (RCT) or non-randomized cohort study. In later reviews by Cicerone et al. (2005; 2011) 9 and 18 additional studies, respectively, were identified. Some of these studies were not included in our review as they did not meet our inclusion criteria. Based on the results of the studies in their review, Cicerone et al. (2000) recommended, "*training of formal problem-solving strategies and their application to everyday situations and functional activities".*

Individuals with ABI who present with executive function deficits may have difficulties with everyday problem solving, planning and organising activities, prioritizing tasks, and multi-tasking (Kennedy et al., 2008). Executive function deficits are particularly prevalent in individuals with brain injury who are younger (average age less than 40 years) and often impact re-integration to their pre-injury roles. Individuals with executive function deficits may have the capacity to be independent for basic activities of daily living where actions tend to be more ingrained and one-dimensional. However, instrumental activities of daily living such as banking, scheduling and household activities require intact executive functions due to the increased cognitive complexity and variability of the tasks. Advanced tasks such as return to driving and competitive employment may also be important to the younger individuals with TBI (Miller, Burnett, & McElligott, 2003).

Rehabilitation of Executive Functioning

Non-Pharmacological Interventions

Within the typical medical and rehabilitation settings, executive function deficits are difficult to identify and evaluate. Executive functioning deficits can hinder successful community re-integration; therefore, it is crucial to address executive functioning in individuals with moderate to severe TBI. Although executive function deficits post TBI are common, there is a limited body of research that directly addresses the impact of rehabilitation on executive function.

Biofeedback

Biofeedback is a non-invasive rehabilitative therapy that measures biological information, such as heart rate, providing feedback to the individual, or the therapist, to increase awareness and control over biological processes (Giggins, Persson, & Caulfield, 2013).

TABLE 4 | The Effect of Biofeedback on Executive Function Post ABI

Author, Year Country Study Design Sample Size	Methods	Outcome
Kim et al. (2018) United States Pre-post N=13	**Population:** Median age=40yrs; Gender: Male=7, Female=6; Median time post-injury=23yr. **Intervention:** Heart rate variability biofeedback training was conducted for 10, 1hr sessions. After the fourth session individuals were given	1. HRV biofeedback significantly improved CT scores ($p<.05$), this effect was magnified by those experiencing positive affects during treatment as measured by the PANAS. 2. No other significant results were found.

	a portable biofeedback device to take home and self-monitor. **Outcomes Measures:** Category Test (CT), Heart rate variability index (HRV), Positive Affect and Negative Affect Schedule (PANAS).	

Discussion

Kim et al. (2018) used heart rate variability biofeedback to increase awareness and cognitive control in individuals with severe brain injury. In this study, individuals who underwent heart rate biofeedback significantly improved scores of executive functioning on the Category Test. Given that this study had a pre-post design and there was no control group for comparison, results should be interpreted with caution.

Conclusions

There is level 4 evidence that heart rate biofeedback may improve executive functioning following an ABI, although higher level studies are required to fully determine this (Kim et al., 2018).

KEY POINTS

- Heart rate variability biofeedback may improve executive functions; however, randomized controlled trials are required to make further conclusions.

Dual-Task Training

Dual-task training involves completing a primary and secondary task with distinct goals simultaneously, and each task can be completed independently as a single task (Hofheinz, Mibs, & Elsner, 2016). The goal of dual-task training is to complete both tasks simultaneously to improve divided attention, executive functioning, and general cognitive functioning.

TABLE 5 | The Effect of Dual-Task Training on Executive Function Post ABI

Author, Year Country Study Design Sample Size	Methods	Outcome
Couillet et al. (2010) France RCT PEDro=5 N=12	**Population:** severe TBI; Gender: Male=9, Female=3. *Group 1 (n=5)*: Mean Age=23.8yr; Mean GCS=4.8; Mean Time Post Injury=6.3mo. *Group 2 (n=7)*: Mean Age=26.7yr; Mean GCS=4.8; Mean Time Post Injury=16.1mo. **Intervention:** Randomized AB versus BA design, where "A" represents the control phase and "B" represents the treatment (dual-task training) phase. In the dual-task phase,	1. There was a significant improvement in the 2 tasks that targeted divided attention (TAP-divided attention, Go-no go, and Digit Span: p<.0001 for both). 2. The two groups differed significantly at 6 wk with those in the BA design doing better on TAP reaction times (p<.010), the digit span dual-task (p<.001), and the Rating Scale of Attentional Behaviour (p<.010).

	participants were trained to conduct two concurrent tasks simultaneously. Group 1 started with the control phase (AB) and Group 2 (BA) with the treatment phase. Each phase lasted 6wk (4, 1 hr sessions/wk). **Outcome Measures:** Test Battery for Attentional Performance (TAP: divided attention and flexibility subtests), Go-no go and Digit Span, Trail Making Test, Stroop Test, Brown-Peterson Paradigm, Rating Scale of Attentional Behaviour.	3. There was a significant difference between groups at 6wk on the Stroop test (p<.001) and the flexibility subtest of the TAP (p<.001), but not the Trail Making Test or the Brown-Peterson task. 4. Experimental training had no significant effects on non-target measures.

Discussion

Couillet et al. (2010) assessed the effectiveness of a rehabilitation programme for divided attention after severe TBI. Even though individuals improved on measures of attention to a significantly greater extent than controls, no such relationship was found for measures of executive function.

Conclusions

There is level 2 evidence that dual-task training may not improve executive functioning in individuals with TBI (Couillet et al., 2010).

KEY POINTS

- Dual-task training may not improve executive function in individuals with TBI.

Hypnosis

Hypnosis utilizes a highly focused, absorbed attentional state that minimizes competing thoughts and sensations (Oakley & Halligan, 2013). Hypnosis has been used to treat pain, phobias, depression, psychotic and dissociative disorder; additionally, hypnosis has been used as part of the rehabilitation treatment of individuals with severe ABI (Vanhaudenhuyse, Laureys, & Faymonville, 2014, 2015).

TABLE 6 | The Effect of Hypnosis on Executive Function Post ABI

Author, Year Country Study Design Sample Size	Methods	Outcome
Lindelov et al. (2017) Denmark RCT PEDro=7 N=68	**Population:** TBI=34, Stroke=20, Other=12, NA=2. *Group A (n=27)*: Mean Age=45.2yr; Gender: Male=12, Female=15; Mean Time Post Injury=5yr. *Group B (N=22)*: Mean Age=47.0yr; Gender: males=8, females=25; Mean Time Post Injury=6.5yr. *Control Group (n=19)*: Mean Age=54.1yr; Gender: males=8, females=11;	1. In Phase 1, there was significantly more improvement in Group A compared to Group B for WMI (Bayes factor=342) and TMT (Bayes factor=37.5). 2. After the break, the WMI and MT showed no significant differences for either group

	Mean Time Post Injury=7yr. **Intervention:** Participants were randomly assigned to Group A or Group B; Control group was recruited separately and received no intervention. In Phase 1, Group A received the first version of a targeted hypnosis procedure (improving brain injury or working memory-relating abilities) and Group B received a non-targeted hypnosis procedure (4 weekly 1hr sessions). After a 7wk break, Phase 2 occurred, with Group A receiving a second version of a targeted hypnosis procedure and Group B receiving the first version of a targeted hypnosis procedure. **Outcome Measures:** Working Memory Index (WMI), B-A Trail Making Index (TMT).	compared to before the break. Indicating that long-term effects were preserved. 3. In Phase 2, Group B crossed over to the targeted intervention and showed significant improvements in WMI (Bayes factor=535) and TMT (Bayes factor=72813). Group A showed a small improvement for WMI (Bayes factor=1.5) and TMT (Bayes factor=30). 4. From baseline to last test, there were no significant difference in improvements between Group A and Group B for WMI and TMT.

Discussion

Lindelov et al. (2017) examined the effects of targeted hypnosis, as delivered in a targeted or non targeted manner, on working memory performance in participants with ABI. The authors found that targeted hypnotic suggestion may improve working memory and executive function in individuals with ABI, as measured by the Working Memory Index (WMI) and the Trail Making Test (TMT), respectively. Long-term effects of targeted hypnosis were preserved even after a no-contact period, suggesting some degree of residual capacity for normal information processing in individuals with ABI (Lindeløv et al., 2017).

Conclusions

There is level 1b evidence that targeted hypnosis may improve executive function in individuals with ABI (Lindeløv et al., 2017).

KEY POINTS

- Targeted hypnosis may improve working memory and executive function in individuals with ABI.

General Cognitive Rehabilitation Programs

Cognitive rehabilitation programs involve a variety of interventions to assist individuals with TBI regain cognitive function through individual and group therapy. Given the considerable heterogeneity of the treatment methods, comparing interventions may be difficult (Cicerone et al., 2005).

TABLE 7 | The Effect of General Cognitive Rehabilitation Programs on Executive Function Post ABI

Author, Year Country Study Design Sample Size	Methods	Outcome
Vas et al. (2011) USA RCT PEDro=6 N=28	**Population:** TBI: *Strategic Memory and Reasoning Training (SMART) Group* (n=14): Mean Age=39yr; Gender: Male=9, Female=5; Mean Time Post Injury=16.71yr. *Brain Health Workshop Group* (n=14): Mean Age=47yr; Gender: Male=7, Female=7; Mean Time Post Injury=16.35yr. **Intervention:** Participants were randomly assigned to the SMART group or the BHW group. Participants received a total of 12 group sessions over an 8wk period. The SMART group learned about strategies they could apply in their daily lives; homework was given at the end of each session. The BHW group sessions were designed to be information-based and reading assignments were given each week. Participants were assessed at baseline, post-training (3wk) and at a 6mo follow-up. **Outcome Measures:** Test of Strategic Learning (TOSL); Working memory listening span task; Community Integration Questionnaire (CIQ); Wechsler Adult Intelligence Scale III (WAIS III).	1. The SMART group had significantly greater TOSL scores compared to the control group post-training (SMART *Mean*=19.76, BHW *Mean*=13.69, p=.030). 2. The SMART group had significant improvements in TOSL scores: post-training (*Mean*=19.76, p=.007) and at 6-month follow-up (*Mean*=21.15, p=.004) from baseline (*Mean*=14). 3. The SMART group had significantly greater improvements than the control group on the working memory listening span task post-training (SMART *Mean*=4.23, BHW *Mean*=2.59, p<.001). 4. The SMART group had significant improvements post-training in the working memory listening span task (*Mean*=4.23, *p*=.005) and at 6-month follow-up (*Mean*=4.96, P=.0001) compared to baseline (*Mean*=2.76). 5. The SMART group had significantly greater improvements on CIQ compared to the BHW group (SMART *Mean*=18.73, BHW *Mean*=16.45, p=.020). 6. The SMART group had significant improvements in the CIQ at the 6-month (*Mean*=19.88, p=.010) follow-up from baseline (*Mean*=15.19). Those in the SMART group showed significant improvement on 3 executive functions following training (inhibition: p=.010; nonverbal reasoning: p=.001; and cognitive flexibility: p=.010) on the WAIS-III.
Spikman et al. (2010) Netherlands RCT PEDro=7 N=75	**Population:** ABI; Mean Age: 42.5yr; Gender: male=50, female=25; Condition: TBI=33, Stroke=32, Other=10. **Intervention:** Individuals were randomly assigned to either the experimental group which comprised of multifaceted strategy training (n=38) or the control group (n=37). The primary goal of the treatment group was to improve 8 aspects of executive functioning. **Outcome Measures:** Role resumption list (RRL); treatment goal attainment (TGA) and Executive Secretarial Task (EST).	1. The experimental group improved significantly more over time than the controls on the RRL and attained significantly higher scores on the TGA and EST (p<.010).
Constantinidou et al. (2008) United States RCT PEDro=8	**Population:** *Experimental Group (N=21)*: Mean age=32.1yr; Mean time post-injury=9.74mo. *Control Group (N=14)*: Mean age=27.57yr; Mean time post-injury=10.55yr.	1. The experimental group significantly improved on CP Test 1 (object recognition) compared to the control group (p=.039). 2. Individuals in the experimental group performed significantly better on the CP Test 2

N=35	**Intervention:** Individuals received either the Categorization Program intervention for 13wk averaging 4.5hrs/wk, or 'regular therapy' (control group). **Outcomes Measures:** CP Test 1 (object recognition/memory), CP Test 2 (executive functioning), CP Probe Tasks (executive functioning), Community Reintegration Questionnaire (CIQ), Mayo-Portland Adaptability Inventory (MPAI-3), California Verbal Learning Test (CVLT), Rey Complex Figure Test (RCF), Wechsler Memory Scale (WMS-III), Woodcock Johnson (WJ-III), Scales of Cognitive Ability for Traumatic Brain Injury (SCATBI).	(executive functioning) compared to the control group post-intervention (p=.010). 3. Individuals in the experimental group performed significantly better on the probe tasks, compared to controls, post-treatment (p=.008). 4. Individuals in both groups significantly improved performance on the CIQ and MPAI-3 (p<.05). 5. The experimental group had greater improvement on the CVLT-R. 6. There were no differences in scores between groups on the RCF, WMS-III, WJ-III, SCATBI.
Sohlberg et al. (2000) USA RCT PEDro=8 N=14	**Population:** TBI=11, ABI=1, Other=2. *Attention Process Training (APT) Group (n=7)*: Mean Age=33.1yr; Mean Time Post Injury=7.5yr; *Control Group (n=7)*: Mean Age=38.1yr; Mean Time Post Injury=1.6yr. **Intervention:** Participants were randomized to receive either the APT training (treatment) or the brain injury education and supportive listening (control), in a cross over design. APT was 24hr over 10wk and the control group received 10hr over 10wk. All subjects worked directly with a therapist and assessed pre and post intervention. **Outcome Measures:** Trail Making Test, Paced Auditory Serial Addition Task (PASAT), Gordon Diagnostic Vigilance and Distraction, Controlled Oral Word Association Task (COWAT), Stroop Task, Attention Questionnaire.	1. Those in the APT group reported significantly more changes than the control group (0.91 and 0.58 respectively, p<.050). 2. The effect of type of change was significant (p<.0001); a greater number of memory/ attention changes were reported for the APT group, whereas more psychological changes were reported for the control. 3. Changes in PASAT scores corresponded with perceived cognitive improvement in the interview; changes in PASAT scores were greater for those who reported >2 cognitive changes (p<.050). 4. Results of the PASAT, Stroop Task, Trail Making Test B, and COWAT also found that those with higher levels of vigilance had improved scores (p<.01). 5. For the aforementioned tasks, there were also specific improvements in performance associated with APT that were greater than those associated with brain injury education (p<.050).
Holleman et al. (2018) Netherlands PCT N=75	**Population:** *Experimental Group (N=42):* Mean age=43.3yr; Gender: Male=27, Female=15; Mean time post-injury=7.9yr. *Control Group (N=33)*: Mean age=40.7yr; Gender: Male=20, Female=13; Mean time post-injury=6.9yr. **Intervention:** Participants were either assigned to the Intensive NeuroRehabilitation programme or the control group. The programme took place over the course of 16wk and consisted of 2 groups of 7wk of training with a 2wk break in between. Individuals had 5hr of training 4d/wk in a group setting. **Outcome Measures:** Symptom checklist (SCL), Beck Depression Inventory-II (BDI-II), Hospital Anxiety and Depression Scale (HADS), Zelfbeeldenvragenlijst-trait (ZBV), Quality of Life in Brain Injury (QOLIBRI), Trail making test Part A, Stroop test, Wechsler Adult Intelligence Scale-III (WAIS-III), Rey Auditory Verbal	1. There were no significant between group differences pre-intervention on any measures. 2. Following the intervention, the experimental group had significantly lower SCL scores indicating a reduction in overall symptoms (p=.005). 3. On measures of neuropsychological functioning, the experimental group reported significantly lower scores on the BDI-II (p=.001), HADS (p<.01), and ZBV-trait (p=.002) showing improvement on these neuropsychological measures. 4. The experimental group reported significantly higher scores for quality of life on the QOLIBRI (p<.05). On measures of cognitive functioning no significant differences were seen for any outcome measures.

	Learning Test, Rivermead Behavioural Memory Test, Groninger Intelligentie Test 2, Trail making test Part B.	
Gabbatore et al. (2015) Italy Pre-Post $N_{Initial}$=20, N_{Final}=15	**Population:** TBI; Mean Age=36.7yr; Gender: Male=10, Female=5; Mean Time Post Injury=76.1mo; Mean GCS=4.5. **Intervention:** Participants completed a cognitive group rehabilitation program focused on mental representations underlying one's behaviours (2d/wk for 3mo). Each session consisted of comprehension activities (discussing specific communication modalities) and production activities (role-playing activities). Participants were assessed at T0 (3mo before intervention (regular activities during this time), T1 (before intervention), T2 (after intervention) and T3 (3mo follow-up – regular activities during this time). Total study duration was 9mo. **Outcome Measures:** Assessment Battery for Communication (AbaCo-comprehension, production, linguistic, extralinguistic, paralinguistic, and context), Verbal Span Task (VST), Spatial Span Task (SST), Attentive Matrices Test (AMT), Trail Making Test (TMT), Tower of London Test (TOL), Colored Progressive Matrices Raven (CPM Raven), Aachener Aphasie Test-Denomination Scale (AAT), Sally-Ann Task, Strange Stories Task, Immediate and Deferred Recall Test (IDR), Wisconsin Card Sorting Test (WCST).	1. No significant improvements in AbaCo (production and comprehension) were observed from T0 to T1. 2. Participants showed significant improvements from T1 to T2 for AbaCo comprehension (p<.001), production (p<.001), linguistic (p=0.005), extralinguistic (p=.008), paralinguistic (p=.02), and context (p=.01). 3. The improvements made during the treatment period were stable between T2 and T3 for both Comprehension (p=.86) and Production (p=.32). At T3, AbaCo scores did not show significant differences from T2. 4. There was no significant difference between T1 and T2 on the VST (p=.49), SST (p=.74), AMT (p=.35), TMT (p=.45), TOL (p=.50), CPM Raven (p=.09), AAT (p=.22), Sally-Ann (p=.58), or strange stories task (p=1.00). There was a significant improvement between T1 and T2 on the IDR (p=.01) and WCST (p=.003).
Fong & Howie (2009) China PCT N=33	**Population:** Mean age=33.4yr; Gender: Male=27, Female=6; Mean time post-injury=12.3mo. **Intervention:** The experimental group received enhanced problem-solving skills training program, using a meta-componential approach, in addition to the standard cognitive rehabilitation training program received by the control group. **Outcome Measures:** Key Search test, Social Problem-Solving Video Measure (SPSVM), Means-Ends Problem-Solving Measure (MEPSM), Raven's Progressive Matrices (RPM), Metacomponential Interview (MI).	1. No significant differences were found on the Key Search test, the SPSVM, RPM, or the MEPSM between groups following intervention. 2. There were significant between group differences on two of the categories for the MI; correctness of representation scores (p=.041), and total average correct scores (p=.009). No other significant differences were found.

Discussion

Vas et al. (2011) implemented the Strategic Memory and Reasoning Training (SMART) program. The authors compared its use to that of a brain health workshop. The SMART group had significantly higher scores on the Test of Strategic Learning and the Wechsler Adult Intelligence Scale III for sections

examining inhibition, non-verbal reasoning, and cognitive flexibility. This study demonstrated that the SMART training program may be effective to remediate executive function deficits (Vas et al., 2011).

Gabbatore et al. (2015) examined the efficacy of Cognitive Pragmatic Treatment (CPT) on communicative-pragmatic abilities, including cognitive components such as awareness and executive functions, in individuals with severe TBI. Intervention activities included memory and attention related tasks, socializing activities (e.g., recreation, games), and intellectual creative activities (e.g., reading, cooking, painting). The authors found that the CPT program was effective in improving communicative-pragmatic abilities and the components involved, including executive function (Gabbatore et al., 2015).

In an RCT, Spikman et al. (2010) randomly divided a group of individuals who had sustained a TBI to either a computerized cognitive function training group or a control group. Those in the treatment group were taught a comprehensive cognitive strategy which allowed them to tackle the issues and problems of daily living, compared to the control group which received a computerized training package that was aimed at improving general cognitive functioning. Overall, results indicated that both groups improved on many aspects of executive functioning; however, those in the treatment group showed greater improvement in their ability to set and accomplish realistic goals and to plan and initiate real life tasks (Spikman et al., 2010).

In an RCT, Constantinidou et al. (2008) examined the effectiveness of a Categorization Program (CP) on cognitive abilities in individuals with TBI. The authors found that the CP resulted in both groups performing better in neuropsychological test performance and on functional outcome tests. However, improvements were more prevalent in the experimental group (Constantinidou et al., 2008).

With respect to Attention Process Training (APT), Sohlberg et al. (2000) found that this intervention may have indirectly improved executive function as individuals with higher vigilance achieved higher executive function scores, but it was not explicitly demonstrated that training resulted in increased vigilance (Sohlberg et al., 2000).

Holleman et al. (2018) examined the effect of an intensive NeuroRehabilitation programme on the emotions and behaviours of individuals with ABI. The intervention aimed to enhance individuals' awareness and insight into changes experienced after their injury, including cognitive, emotional, and behavioural consequences. The authors found no significant differences between groups on any cognitive measures (Holleman et al., 2018).

Fong and Howie (2009) compared an experimental training intervention with this a problem-solving approach, which taught metacomponential strategies, with a conventional cognitive training approach that did not have an explicit metacognitive training. The authors found that the experimental group exhibited significant advantages; however, transfer to problem solving in real-life measures was not significant.

Conclusions

There is level 1b evidence that the Strategic Memory and Reasoning Training (SMART) program is more effective than a brain health workshop for improving executive function, metacognition, and comprehension following ABI (Vas et al., 2011).

There is level 4 evidence that a cognitive pragmatic treatment (CPT) program may improve communicative-pragmatic abilities, including cognitive components such as awareness and executive functions, in individuals with severe TBI (Gabbatore et al., 2015).

There is level 1b evidence that a comprehensive cognitive strategy that addresses problems of daily living may improve executive functioning in daily life in individuals with ABI (Spikman et al., 2010).

There is level 2 evidence that an explicit problem-solving skills training program using a metacomponential approach may be effective at improving metacomponential functioning but this improvements were not translated to real-life situations for individuals with ABI (Fong & Howie, 2009).

There is level 1b evidence that Categorization training may improve cognitive functioning, including executive function, in individuals with TBI (Constantinidou et al., 2008).

There is level 1b evidence that Attention Process Training (APT) may be improve performance in tasks that required executive function (Sohlberg et al., 2000).

There is level 2 evidence that the Intensive NeuroRehabilitation programme, compared to no treatment, does not improve executive functioning in individuals with ABI (Holleman et al., 2018).

KEY POINTS

- The SMART program may be effective for improving executive functioning following an ABI.
- A cognitive pragmatic treatment (CPT) program may improve communicative-pragmatic abilities, including executive function, in individuals with severe TBI.
- A comprehensive cognitive strategy that addresses problems of daily living may improve executive functioning in daily life in individuals with ABI.
- Categorization training may improve executive function in individuals with TBI
- Attention Process Training likely improves performance in executive functioning.
- An explicit problem-solving skills training program using a metacomponential approach may not be effective at improving execute e function.

Goal Training

Goal Management Training

Goal management training (GMT) is a metacognitive intervention that promotes a mindful approach to completing complex activities by facilitating the implementation of self-instruction strategies, self-monitoring, planning techniques, prospective memory and cognitive control, and mindfulness (Krasny-Pacini, Chevignard, & Evans, 2014).

TABLE 8 | The Effect of Goal Management Training on Executive Function Post ABI

Author, Year Country Study Design Sample Size	Methods	Outcome
Tornas et al. (2016) Norway RCT PEDro=9 $N_{Initial}$=70, N_{Final}=67	**Population:** TBI=45, Stroke=15, Tumor=6, Anoxia=2, Other=2. Mean Age=42.89yr; Gender: Male=38, Female=32; Mean Time Post Injury=97.47mo. **Intervention:** Participants were randomized to receive Goal Management Training (GMT) or Brain Health Workshop (CG) group sessions. GMT group (n=33) discussed distinctions between absentmindedness/presentmindedness, slip-ups in daily life, habitual responding, stopping, and thinking, working memory, importance of goals, defining/splitting goals into subtasks, and checking. BHW control group (n=37) discussed brain function/dysfunction, brain plasticity, memory, executive function, and attention. Treatment was received one day every second week, for a total of 8, 2hr sessions distributed over 4d. Outcomes were assessed at baseline (T1), after treatment (T2), and at 6mo follow-up (T3). **Outcome Measures:** Behaviour Rating Inventory of Executive Function–Adult (BRIEF-A); Dysexecutive Questionnaire (DEX); Cognitive Failures Questionnaire (CFQ); Continuous Performance Test II (CPT-II); UCSD Performance-Based Skills Assessment (UPSA); Delis-Kaplan Executive Function System Battery–Colour-Word Interference Test (CWI), Verbal Fluency Test (VFT), and Tower Test (TT); Trail Making Test (TMT); Hotel Task (HT).	1. In the GMT, significant improvements were found on BRIEF-A, DEX, and CFQ at T3 (p<.01). 2. In the CG, significant improvements were found on only BRIEF-A at T2 (p<.05). 3. The GMT showed significant improvements on BRIEF-A and DEX (p<.01), but not CFQ, compared to the CG over time 4. In the GMT, significant improvements were found on CPT-II, CWI, TT, and HT at T2 and T3 (p<.05), VFT at T3 (p<.05), and UPSA at T2 (p<.001). 5. In the CG, significant improvements were found on CPT-II, TT, and HT at T2 and T3 (p<.050), and VFT and UPSA at T2 (p<.050). 6. The GMT showed a significant improvement on CWI, VFT, and TT (p<.050), but not CPT-II, UPSA, and HT, compared to the CG over time. 7. No significant differences were found on TMT within or between groups over time.
Tornas et al. (2019) Norway $N_{Initial}$=67, N_{Final}=50 **5yr Follow-up to:** Tornas et al. (2016) Norway RCT PEDro=9 Ninitial=70, Nfinal=67	**Population:** TBI=29, Stroke=13, Tumor=6, Anoxic/other=2. Mean Age=45.8±10.9yr; Gender: Male=27, Female=23; Mean Time Post Injury=104.9±128.1mo. **Intervention:** Participants were randomized to receive Goal Management Training (GMT) or Brain Health Workshop (BHW) group sessions. GMT group (n=33) discussed distinctions between absentmindedness/ present mindedness, slipups in daily life, habitual responding, stopping, and thinking, working memory, importance of goals, defining/splitting	1. A significant main effect of time was found for all BRIEF-A indexes between baseline and 6mo follow-up. 2. A significant time by group interaction for the Behavioural Regulation Index; the GMT-group showed a significant increase in behavioural regulation index symptoms that the BHW group did not 3. There was no significant difference found between baseline and 5yr follow-up in either group on the BRIEF-A or QOLIBRI.

	goals into subtasks, and checking. BHW control group (n=37) discussed brain function/dysfunction, brain plasticity, memory, executive function, and attention. Treatment was received 1d every other wk, for a total of eight, 2hr sessions distributed over 4d. Outcomes were assessed at baseline (T1), after treatment (T2), and at 6mo follow-up (T3). This was a 5yr follow-up. **Outcome Measures:** Behavior Rating Inventory of Executive Function- Adult Version (BRIEF-A), the Quality of Life after Brain Injury (QOLIBRI).	
Elbogen et al., (2019) USA RCT PEDro=8 $N_{Initial}$=112, N_{Final}=89	**Population:** TBI=64; *Treatment Group (n=57):* Mean Age=36.77±8.60yr; Gender: Male=43, Female=4; Mean Time Post Injury= Not Reported; Severity: Mild=22, Moderate-to-Severe=35. *Control Group (n=55):* Mean Age=36.25±8.30yr; Gender: Male=50, Female=5; Mean Time Post Injury=Not Reported; Severity: Mild=, Moderate-to-Severe=29. **Intervention:** Participants were randomized to receive cognitive rehabilitation with a novel program – Cognitive Applications for Life Management (CALM; Treatment Group) or psychoeducation on TBI (Control Group). The program focuses on goal management and brain health training utilizing mobile technology and social support. Participants completed three 60-90min sessions at 0, 2 and 4mo. Outcome measures were assessed at baseline and 6mo post randomization. **Outcome Measures:** Delis-Kaplan Executive Dysfunction System (DKEFS), Barratt Impulsiveness Scale (BIS), Dimensions of Anger Reactions (DAR), Head Injury Behaviour Scale (HIBS), Clinician Administered Posttraumatic Stress Disorder Scale (CAPS).	1. No significant improvements were observed in measures of executive function (DKEFS; p>0.05) or impulsiveness (BIS; p>0.05) with the CALM intervention at 6mo. 2. Significant improvements in measures of emotion (DAR; p<0.05) and behavioural regulation (HIBS; p<0.05) were observed with the CALM intervention at 6mo. 3. Participants receiving calm reported a 25% decrease in anger compared to 8% in the control group at 6mo (p=0.008). 4. Family/friends of participants reported that participants receiving the CALM intervention had 26% fewer maladaptive interpersonal behaviours than 6% of those in the control group at 6mo (p=0.016).
Gracey et al. (2017) UK RCT PEDro=6 $N_{Initial}$=74, N_{Final}=59	**Population:** CVA=23, Infection=3, TBI=33, Tumor=10, Missing=1. *Control First (n=34)*: Mean Age=50.18yr; Gender: Male=23, Female=11; Mean Time Post Injury=8.62yr. *Assisted Intention Monitoring (AIM, n=36)*: Mean Age=46.36yr; Gender: males=23, females=13; Mean Time Post Injury=4.89yr. **Intervention:** Participants were randomized to receive AIM or control first. In the AIM-first group, participants received goal management training followed by text messages for improving achievement of everyday intentions. Control-first group received brain injury information, Tetris game, and non-informational text messages. After 3wk, participants were crossed over with AIM-first	1. Participants achieved a greater proportion of intentions during the AIM intervention relative to control (p=.040). 2. Participants achieved a greater proportion of goal attainment (without the phone call task) during the AIM intervention relative to control (p=.033). 3. No significant Group x Time interaction effect was found for the POMS MD or Hotel Test. 4. When only comparing group differences at post-intervention phase 1, intention to treat analysis showed no significant difference between groups for proportion of intentions achieved or achievement of goals excluding the phone task.

	group receiving usual care and control-first group receiving AIM. **Outcome Measures:** Mean daily proportion of intentions achieved, Achievement of all goals excluding the phone call task, Profile of Mood States total mood disturbance (POMS MD), Hotel Task, Verbal Fluency.	
Levine et al. (2000) Canada UK RCT PEDro=4 N=30	**Population:** TBI: *Goal Management Training (GMT) Group* (n=15): Mean Age=29.0yr; Gender: Male=5, Female=10; Mean GCS=10.7; Mean Time Post Injury=3.7yr. *Motor Skill Training (MST) Group* (n=15): Mean Age=30.8yr; Gender: Male=9, Female=6; Mean GCS=10.8; Mean Time Post Injury=3.8yr. **Intervention:** Participants were randomized into the GMT or MST group. The GMT was comprised of five steps: 1) orienting and alerting to task, 2) goal selection, 3) partitioning goals into sub-goals, 4) encoding and retention of sub-goals, and 5) monitoring. The MST was training that was unrelated to goal management: reading and tracing mirror-reversed text and designs. Participants were tested on everyday paper and pencil tasks that focused on holding goals in mind, sub-goal analysis and monitoring. **Outcome Measures:** Goal Neglect (Everyday paper and pencil tasks), Stroop Interference Procedure, Trail Making A and B, Wechsler Adult Intelligence Scale Revised (WAIS-R).	Everyday paper and pencil Task 1. The GMT group compared to the MST group had significantly greater accuracy on the everyday paper and pencil tasks post-training ($p<.05$). 2. The MST group also had significantly more errors during the everyday paper and pencil tasks ($p<.01$). 3. The GMT group significantly reduced their errors from pre-post training during the everyday paper and pencil tasks ($p<.01$). 4. The GMT also devoted significantly more time to proofreading and the room-layout tasks than the MST group from pre- to post-training ($p<.05$). Neuropsychological Tasks 1. The GMT group was generally slower on timed neuropsychological tests: Stroop Interference Procedure, Trail Making Part A and B ($p<.05$ and $p<.06$, respectively). 2. No significant differences between groups for the WAIS-R ($p>.05$).

Discussion

In an RCT, Levine et al. (2000) compared a group of participants using Goal Management Training (GMT) strategies to a control group who were received only motor skills training. The treatment group improved on paper and pencil everyday tasks, as well as meal preparation, which the authors used as an example of a task heavily reliant on self-regulation in comparison to the motor treatment group. Results from this study indicated that GMT is an effective intervention for the rehabilitation of executive functioning (Levine et al., 2000).

Group interventions showed the effectiveness of GMT in enhancing executive function. Tornas et al. (2016) compared the effect of group Goal Management Training (GMT) to a group Brain Health workshop (CG) on cognitive outcomes post brain injury. The authors found that individuals receiving GMT improved significantly in cognitive and executive outcomes after treatment, and at 6-month follow-up. While this study showed promising results, the patient population was very heterogenous and it is unclear how different injuries impacted the outcomes. In a five-year follow-up to this study, Tornas et al. (2019) examined the long-term benefits of GMT and found no significant difference between groups on measures of executive function. These findings suggested that the significant improvements related to GMT on executive function that were observed at 6-month follow-up were no longer present after 5

years; therefore, promoting long-term follow-up of clinical interventions is recommended (Tornas et al., 2019).

When combined with mobile technology, GMT has not demonstrated to be effective for the remediation of executive dysfunction. Elbogen et al. (2019) randomized participants, including an individual with TBI and a caregiver, to two different groups. One group received the Cognitive Application for Life Management (CALM) intervention, including goal management training (GMT) and the use of mobile devices. A different group received Brain Health Training, including psychoeducation and mobile devices. Results indicated negative findings related to executive dysfunction in participants (Elbogen et al., 2019). Similar results were found by Gracey et al. (2017), who examined the effectiveness of pairing GMT with SMS text messages for individuals with ABI. The authors found that, while the intervention was effective in achieving daily intentions, no statistically significant differences were found on tests of executive functioning (Gracey et al., 2017).

Conclusions

There is level 1b evidence that Goal Management Training (GMT), may be effective for the remediation of executive functioning in individuals with ABI (Levine et al., 2000; Tornas et al., 2016; Tornas et al., 2019).

There is level 1b evidence that Goal Management Training (GMT) combined with the use of mobile technology may not be effective in improving executive function in individuals with ABI (Elbogen et al., 2019; Gracey et al., 2017).

KEY POINTS

- Goal Management Training may improve executive function in individuals with TBI; however, this intervention may not be effective when combined with mobile technology.

Goal Directed Self-Regulation Training

To accomplish a goal, following a sequence of steps (subgoals) and maintenance of goal-related information is important. Goal directed self-regulation training aims to help participants to decrease their failures on complex functional tasks (Novakovic-Agopian et al., 2011).

TABLE 9 | The Effect of Goal Directed Self-Regulation Training on Executive Function Post ABI

Author, Year Country Study Design	Methods	Outcome

Sample Size		
Chen et al. (2011) USA RCT PEDro=5 N=12	**Population:** TBI=9, Other=3: Mean Age=48yr; Gender: Male=5, Female=7; Time Post-Injury Range=6mo-6yr. **Intervention:** Participants were randomized to receive either the goals training intervention (n=7) or education intervention (n=5) for 5wk, after which they switched to the other condition for another 5wk. The intervention was designed to treat goal-directed attention regulation. The goals training was spread over 5wk and involved: group, individual and home-based training. The education program was a 5wk didactic educational instruction regarding brain injury. **Outcome Measures:** Letter number sequencing, Wechsler Adult Intelligence Scale-III, Auditory consonant trigrams, Digit Vigilance Test, Design and Verbal Fluency Switching, Trails B, Stroop Inhibition, Hopkins Verbal Learning Test, Brief Visual Memory Test Revised, Trails A test, Visual Attention Task.	1. On the domain of attention and executive functions, all participants in the goal training intervention showed an increase from pre to post goals training; while only 7/12 in the education intervention showed an increase from pre to post education (p<.0001). 2. For learning and memory performance scores increased an average of 0.70 units after participation in goals training than after participation in education intervention (p=.020). 11/12 participants improved in the goals training group while 4/12 improved in the education group (p=.009). 3. Tests of motor speed of processing showed no significant differences between the two interventions with a non-significant trend for greater improvements in goal-training compared to education (p=.070). 4. All 12 participants showed an increase in performance scores in the domain of Attention and Executive Functions from pre- to post-goals training
Novakovic-Agopian et al. (2011) USA RCT Crossover PEDro=5 N=16	**Population:** TBI=11, Stroke=3, Other=2: Mean Age=50.4yr; Gender: Male=7, Female=9; Time Post Injury Range=1-23yr. **Intervention:** Participants were randomized to 5wk interventions consisting of a goals training program (n=8) or an educational instruction group (n=8). Goal training focused on mindfulness-based attentional regulation and goal management strategies for participant-defined goals. Educational training was didactic instructional sessions about brain injury. At the end of 5wk, participants were switched to the other intervention. All participants were assessed at baseline, 5 and 10wk. **Outcome Measures:** Auditory Consonant Trigrams, Letter Number Sequencing (working memory); Digit Vigilance Test (sustained attention); Stroop Inhibition Delis-Kaplan Executive Function System (Inhibition); Trails B, Design Fluency-switching (mental flexibility), Hopkins Verbal Learning Test-Revised, Brief Visual Memory Test-Revised.	1. At the end of 5wk participants in the goals-edu group showed significant improvement on measures of attention and executive function from baseline (p<.0001), while the edu-goals group showed no change or minimal change (p>.05). 2. The goals-edu group had significantly greater improvements than the edu-goals group on the following at 5wk: working memory (M*ean* 1.12 versus -0.12, p<.0001); mental flexibility (*Mean* 0.64 versus 0.04, p=.009); inhibition (*Mean* 0.62 versus 0.04, p=.005); sustained attention (*Mean* 0.96 versus 0.27, p=.010); learning (*Mean*=0.51 versus 0.08, p=.020); and delayed recall (*Mean* 0.39 versus -0.27, p=.010). 3. At wk 10, the edu-goals group significantly improved compared to wk 5 on: attention and executive function (0.79 versus 0.03, p<.0001); working memory (1.31 versus -0.12, p<.0008); mental flexibility (0.66 versus 0.04, p<.0008); inhibition (0.50 versus 0.04, p=.010); sustained attention (0.44 versus 0.27, p=.010); memory (0.609 versus -0.10, p=.020); learning (0.66 versus 0.08, p=.050); and delayed recall (0.55 versus -0.27, p=.020). 4. Those in the goals-edu group who had completed the training session were able to maintain their gains and there were significant improvements in attention and executive function (p<.040) and working memory (p<.020).

Cizman et al., (2020) Slovenia Pre-Post $N_{Initial}$=7, N_{Final}=7	**Population:** TBI=6; Mean Age=34±18.6yr; Gender: Male=5, Female=2; Mean Time Post Injury=4±1.25mo; Severity: Mild=0, Moderate=2, Severe=4. **Intervention:** Participants completed a Goal-Orientated Attentional Self-Regulation (GOALS) training program consisting of ten 2hr group sessions twice a wk, 3hr of individual therapy with a psychologist and 20hr of self-training at home. The program focused on cognitive and social skill training, as well as psychoeducation. Outcome measures were assessed at baseline and conclusion of the program. **Outcome Measures:** Alertness and Distractibility, Mobility Version of Test of Attentional Performance (TAP-M), Repeatable Battery for the Assessment of Neuropsychological Status (RBANS), Letter Fluency Test, Tower of London Test, Stroop Interference Test, Clinical Assessment of Depression (CAD).	1. No significant differences in reaction times were observed on the Alertness and Distractibility task when compared to baseline (p>.05). 2. No significant improvements were observed in measures of executive function (Tower of London, STROOP, and Verbal Fluency; p>.05). However, TAP-M performance significantly worsened when compared to baseline (p<.05). 3. List learning and story delayed recall measures of the RBANS significantly improved from baseline (p=.028, p=.043), while the remainder of RBANS measures were not significant (p>.05). No significant differences in ratings of depression or anxiety were observed from baseline (p>.05).

Discussion

In an RCT, Novakovic-Agopian et al. (2011) found that the goal directed self-regulation training group showed significant improvement on attention and executive function assessments compared to the educational group. Despite switching interventions at the 5-week mark to the educational intervention, the goal directed self-regulation training group continued to improve significantly. Chen et al. (2011) also found improvements in executive functions. In a pre- post- study, Cizman Staba et al. (2020) observed positive effects related to the ability of individuals with ABI to hold information, indicating a potential improvement in executive function.

Conclusion

There is level 2 evidence that goal-directed attentional self-regulation training may improve executive function in individuals with ABI (A. J. Chen et al., 2011; Cizman Staba et al., 2020; Novakovic-Agopian et al., 2011).

KEY POINTS

- Goal-directed attentional self-regulation training may improve executive function in individuals with ABI.

Music Therapy

Music therapy interventions involve the use of music (e.g., playing musical instruments, listening to music, singing) as a therapy aid to stimulate brain functions, including movement, cognition, speech, emotions, and sensory perceptions (Magee, Clark, Tamplin, & Bradt, 2017).

TABLE 10 | The Effect of Music Therapy on Executive Function Post TBI

Author, Year Country Study Design Sample Size	Methods	Outcome
Martínez-Molina et al. (2021) Finland RCT Crossover PEDro=7 $N_{initial}$=40 N_{final}=23	**Population:** TBI; Moderate-Severe=23; Mean Age=41.4yr; Gender: Male=10, Female=13; Mean Time Post Injury=7.8mo; Mean GCS=12.9. **Intervention:** Participants were randomized to receive usual care and neuromuscular music therapy (NMT; 60min session, twice per week for 10wk) or usual care only. NMT consisted of rhythmical training, structured cognitive motor training, and assisted music playing. Participants received individual 60min NMT sessions twice per week for a 10wk period. Outcome measures were assessed at baseline, 3mo and 6mo. **Outcome Measures:** Frontal Assessment Battery (FAB), Weschler Adult Intelligence Scale IV (WAIS-IV), Wechsler-Memory Scale III (WMS-III), Number-Letter Task (NLT), Auditory N-back task, Simon Task, Sustained Attention to Response Task (SART), Behavioral Rating Inventory of Executive Function-Adult version (BRIEF-A), Structural MRI (sMRI), Resting-state Functional MRI (rs-fMRI).	1. In the pre- versus post-intervention comparison, there was a significant increase ($p<.05$) in temporal coupling with the sensorimotor, dorsal attention, and frontoparietal after the music-based intervention. 2. NMT increased the coupling between the frontoparietal network and dorsal attention, as well as between primary sensory networks ($p<.05$). 3. Decreased BRIEF-A self-monitor scores correlated significantly with decreased within-network functional connectivity in the left and right lateral prefrontal cortex nodes of the frontoparietal network ($p=.039$) and showed a marginal trend with increased FAB scores ($p=.040$). 4. Participants who showed a larger reduction in connectivity within the frontoparietal network after training exhibited greater improvement in general enhanced function.
Siponkoski et al. (2021) RCT Crossover PEDro=5 N=38	**Population:** TBI: *Moderate-Severe; AB Group (n=20):* Mean Age=41.6yr; Gender: Male=10, Female=10; Mean Time Post Injury=8.6mo. *BA Group (n=18):* Mean Age=41.8yr; Gender: Male=12, Female=6; Mean Time Post Injury=9.8mo. Caregivers of the patients=33. **Intervention:** Participants were randomized into two groups (AB and BA). For the duration of the first 3mo, the AB group received neurological music therapy in addition to standard care, whereas the BA group received only standard care. Both groups received treatment for 60 min/d, 2d/wk and switched halfway through the study period after 3mo. Outcome measures were assessed at 3, 6, and 18mo. **Outcome Measures:** Behaviour Rating Inventory of Executive Function- Adult version (BRIEF-A), Quality of Life after Brain Injury	1. The AB group showed a significant improvement in self-reported BRIEF-A Behaviour Regulation Index (BRI), as indicated by lowering of the BRI score compared to the BA group between time baseline and at 3 months. The change within the BA group did not reach significance ($p=.275$). 2. No significant interactions were found in the other BRIEF-A indices or in the other questionnaires (BDI-II, QOLIBRI). 3. The only domain in which the numeric ratings of participants with TBI and the caregivers differed significantly was Motor: participants with TBI experienced more benefits in motor functioning than the caregivers ($p=.008$). 4. Participant feedback revealed that many participants experienced the intervention as helpful in terms of emotional well-being and activity.

	(QOLIBRI), Global Executive Composite Index (GECI), Beck Depression Inventory II (BDI-II).	
Siponkoski et al. (2020) Finland RCT-Crossover PEDro=8 N= 40	**Population:** TBI; Mean Age=41.3±13.3yr; Gender: Male=23, Female=16; Mean Time Post Injury= 8.9±6.4mo; Mean GCS= 11.8±4.2. **Intervention:** Participants were randomized to either neurological music therapy and standard care (n=20) or standard care only. Neurological music therapy (adapted from Functionally-Oriented Music Therapy and Music-Supported Training) was 20 sessions (2/wk, 1hr each) by a music therapist. Each session contained rhythmical training, structured cognitive-motor training, and assisted music playing. Assessments were conducted at baseline (T1), 3mo (crossover, T2) and 6mo (T3). **Outcome Measures**: Frontal Assessment Battery (FAB), Number-Letter Task (NLT), Auditory N-back Task, Simon Task, Sustained attention to response task (SART), Wechsler Adult Intelligence Scale IV (WAIS-IV).	1. There was significant time X group interaction for executive function (FAB; p=.045) with the music therapy block showing greater improvement in executive function than the control group. 2. No significant between group differences were found between T1 and T2 for reasoning, verbal memory, or motor performance. 3. There was significant improvement for the NLT error rate for the music therapy block compared to the control block (p=.032); however, no significant between group differences were found for the other computerized executive functioning/attention tests.

Discussion

Martinez-Molina et al. (2021) analyzed resting-state fMRI data to assess networks associated with cognition impairment in individuals with moderate to severe TBI. The neurological therapy session involved 20 individual therapy sessions with a trained music therapist over a period of 3 months. The session targeted rehabilitation of executive function, attention and working memory. In the session, individuals participated in rhythmical training, structured cognitive motor training and assisted music playing. The authors found that neurological music therapy can lead to functional neuroplasticity changes in resting- state networks after a TBI. The authors suggested that repetitive practice during music therapy may reduce cognitive challenge and transfers to better executive functioning (N. Martinez-Molina et al., 2021).

Siponkoski et al. (2020) examined the effectiveness of neurological music therapy in improving executive function in individuals with TBI. The authors found that music therapy can induce neuroanatomical changes, improving general executive function in individuals with TBI, and maintaining the effect in the 6-month post-intervention follow-up (S. T. Siponkoski et al., 2020). In a later study Siponkoski et al. (2021) found that music therapy had a positive effect on everyday executive function, measured by the BRIEF-A Behavioural Regulation Index. This effect was maintained in the 6-month follow-up, indicating that music therapy may enhance executive functioning on the level of daily life performance and social interactions in individuals with TBI.

Conclusions

There is level 1b evidence music therapy may improve executive function in individuals with TBI (Noelia Martinez-Molina et al., 2021; S.-T. Siponkoski et al., 2021; S. T. Siponkoski et al., 2020).

KEY POINTS

- Music therapy may enhance executive function in individuals with TBI.

Dance Therapy

Dance is a performing art that contributes to the integration of mind and body. Dance has been used as therapy for individuals living with TBI and may assist in the development of mind-body awareness (Winters Fisher, 2019).

TABLE 11 | The Effect of Dance Therapy on Executive Function Post TBI.

Author, Year Country Study Design Sample Size	Methods	Outcome
Sarkamo et al. (2021) Finland RCT Crossover PEDro=7 N=11	**Population:** *TBI: Moderate-Severe; AB Group (n=6):* Mean Age=36.3yr; Gender: Male=3, Female=3; Mean Time Post Injury=9.2yr. *BA Group (n=5):* Mean Age=33.7yr; Gender: Male=4, Female=1; Mean Time Post Injury=5.8yr. **Intervention:** Participants with TBI were randomized into two groups and received the dance intervention either during the first 3-month phase (AB group) or the second 3-month phase (BA group). The Dual-Assisted Dance Rehabilitation (DARE) featured a combination of dance training and specialized physical therapy, and was provided for 60 min per day, 2 days a week, for 12 weeks. Outcome measures were assessed at the 3- and 6-month stages. **Outcome Measures:** Montreal Cognitive Assessment (MoCA), Frontal Assessment Battery (FAB), Wechsler Adult Intelligence Scale IV (WAIS-IV), Sustained Attention to Response Test (SART), Beck Depression Inventory II (BDI-II), Behavior Rating Inventory of Executive Function – Adult version (BRIEF-A)	1. 91% of participants were fully consistent with the protocol, and 83-100% of participants self-adhered to DARE sessions. 2. There was a higher than-average benefit for two domains of the questionnaire on self-reported benefits of DARE: Mobility (p=0.013) and Cognition (p=0.032), as well as for the overall benefit score (p<0.001). 3. The most consistent positive, medium-large effect sizes favoring DARE were observed for the Digit Span (p=0.232), Similarities (p=0.005), and Block Design (p=0.297) subtests of the WAIS-IV, indicating improvement in verbal working memory and reasoning ability. 4. Both groups yielded a significant positive change from baseline to post-intervention in WAIS-IV (p=0.005) and BDI-II (p=0.002). 5. There were consistent medium-large positive effect sizes (d = 0.43–1.09) also in the BRI, MI, and GEC scores of the BRIEF-A, indicating an improvement in executive function.

Discussion

The effectiveness of dance therapy for individuals with severe TBI has been observed previously in case studies (Kullberg-Turtiainen, Vuorela, Huttula, Petri, & Sanna, 2019). A RCT by Sarkamo et al. (2021)

examined the feasibility and the effects of a dance-based intervention for individuals living with severe TBI. The intervention demonstrated to be feasible and acceptable. Sessions involved participants directing their attention to their body parts, mentally scanning their body, and following a dance choreography with music, as well as stretching and relaxing at the end of the session. Participants showed meaningful gains in motor and neuropsychological tests. There were consistent medium-large positive effect sizes in the BRIEF-A, indicating the effectiveness of the intervention at improving executive function in individuals with severe TBI.

Conclusions

There is level 1b evidence that a dance program is feasible and may improve executive function in individuals with severe TBI (Sarkamo et al., 2021).

KEY POINTS

- Dance Therapy may improve executive function in individuals with TBI.

Technological Interventions

Computer-Based Interventions

In recent years, a surge in computer technology has allowed for the development of computer-based interventions. Generally, cognitive-based computer programs have demonstrated to be effective on measures of cognitive functioning (Johansson & Tornmalm, 2012). Computerized cognitive training is a low cost, user-friendly and accessible intervention that may improve cognition in individuals with ABI; additionally, computer interventions can be relatively easy implemented in a clinical setting or a in a home environment (Sigmundsdottir, Longley, & Tate, 2016).

TABLE 12 | The Effect of Computer-Based Interventions on Executive Function Post ABI

Author, Year Country Study Design Sample Size	Methods	Outcome
Powell et al. (2019) USA RCT PEDro=4 N=23	**Population:** TBI=17, Stroke/aneurysm=4, Other=6, More than 1 brain injury=3; Mean Age=44 yr; Gender: Male=11, Female=12; Mean Time Post Injury=4 yr. **Treatment:** Coaches were randomly assigned to ProSolv intervention or usual care. Participants new to the outpatient	1. No significant differences between groups were found for knowledge test, PSQ clear thinking, PSQ emotional self-regulation, TBI-SE, or SWLS. 2. The average SUS score reported at post-test was 3.5 for the tutorial and 3.6 for the app, suggesting that on average, ProSolv

	rehabilitation program were randomized to coaches and clients already working with coaches were offered the opportunity to participate in the study with that coach. In six 1 h sessions over 8wk, ProSolv group (n=14) received training on using ProSolv app and Usual Care group (n=9) received usual care including training in goal planning/management, time pressure management, and problem-solving skills. ProSolv group had access to the ProSolv app outside of the sessions as a resource for remembering steps to effective problem solving and creating personalized problem-solution lists. **Outcome Measure:** Project-specific knowledge test, Problem Solving Questionnaire (PSQ clear thinking and emotional self-regulation subscales), Problem Solving Rating Scale (PSRS), TBI Self-Efficacy Questionnaire (TBI-SE), Satisfaction with Life Scale (SWLS), System Usability Scale (SUS).	participants were slightly higher than neutral on whether the program components were usable.
O'Neil-Pirozzi and Hsu (2016) PCT $N_{Initial}$=14 N_{Final}=12	**Population:** TBI=4, CVA=2, Brain tumor=1; Severity: moderate/severe. *Experimental Group (n=7)*: Mean Age=51.3 yr; Gender: Male=5, Female=2; Mean Time Post Injury=20.9 yr; Etiology: TBI=5, CVA=2. *Control Group (n=7):* Mean Age=46.9 yr; Gender: Male=7; Mean Time Post Injury=25.0 yr. **Treatment:** Experimental group participants received BrainHQ, a commercially available online computerized cognitive exercise program (Attention, Brain Speed, Memory, People Skills, Intelligence, and Navigation) for 5 mo, 5 d/wk. Control group participants did not have a private computer and received no intervention. **Outcome Measure:** Number/Percentage of Sessions Completed, Number/Percentage of Sessions Initiated by Participants, Number/Percentage of Sessions Completed Independently by Participants, Mean Amount of External Cures Provided for Session Completion, Wisconsin Card Sorting Test (WCST), Hopkins Verbal Learning Test-Revised (HVLT-R immediate, delayed), Controlled Oral Word Association Test-FAS (COWAT), Trail Making Test (TMT A and B accuracy and speed), Satisfaction with Life Scale (SWLS), Semi-structured interview questions.	1. Of the five experimental group participants that completed the study, they completed an average 87% of sessions, initiated an average 25% of sessions, and independently completed an average 7% of sessions. Two participants needed minimum external cues, two participants needed moderate external cures, and one participant needed maximum external cues. 2. Comparing 3 mo prior to intervention with 1 wk prior to intervention, there were no significant differences within either group for WCST, HVLT-R, COWAT, TMT A or B, or SWLS. 3. There were no significant differences between groups at 1 wk prior to intervention (baseline) for WCST, HVLT-R, COWAT, TMT A or B, or SWLS. 4. Compared to baseline, experimental group showed significant improvement post-intervention for HVLT-immediate (p=0.0255) and SWLS (p=0.0075). There were no significant improvements for WCST, HVLT-delayed, or TMT A or B. 5. Compared to baseline, control group did not show significant differences post-intervention for WCST, HVLT, TMT A or B, or SWL. 6. Compared to control group, experimental group showed significantly higher post-intervention improvements on HVLT-immediate (p=0.0068) and COWAT (p=0.0310). No significant differences between groups were found for changes in WCST, HVLT-delayed, TMT A or B, or SWL.

		7. Of the experimental group participants who completed the study, 60% reported improved everyday thinking abilities, 60% reported improved memory, and 20% reported improved attention, organization, and/or problem-solving skills, but 60% reported they would not continue with exercise program post-study completion.
Chen et al. (1997) USA Case-Control N=40	**Population:** Age=18+ yr; Gender: male=27, female=13; Condition: TBI. **Intervention:** Divided retrospectively into computer-assisted rehabilitation (CACR) and tradition therapy groups. **Outcome Measure:** Neurophysiological Test Scores (WAIS-R; WMS).	1. Both groups made significant post-treatment gains on the neurophysiological test scores ($p<0.050$), with the CACR group making significant gains on 15 measures ($p<0.050$) and the comparison group making significant gains on seven measures ($p<0.005$). 2. However, no significant difference was found between groups on their post-treatment gains.

Discussion

Computer-based interventions have been investigated for their efficacy in improving executive dysfunctions post TBI. Powell et al. (2019) implemented a problem-strategy training intervention using ProSolv, an application that can be used on a smartphone and/or a computer with internet access. The BRIEF-A scale was used to assess executive function; however, no statistically significant results were reported (L. E. Powell et al., 2019). Similar findings were reported by O'Neil-Pirozzi and Hsu (2016). The authors examined the feasibility and effects of BrainHQ, a commercially available online computerized cognitive exercise program. Mixed results for improving executive function were found in participants with moderate to severe cognitive impairments post ABI. Individuals reported positive impacts on daily functioning after the completion of the program; however, no significant results were seen on objective measures (O'Neil-Pirozzi & Hsu, 2016). Chen et al. (1997) studied the effect of computer assisted cognitive rehabilitation versus traditional therapy methods. While measures of attention significantly improved in both groups after treatment, no significant differences were observed between groups on any measures related to executive function (S. H. Chen et al., 1997).

Conclusions

There is level 2 evidence that computer assisted cognitive rehabilitation and computer software programs, such as BrainHQ and ProSolv, may not be effective at improving executive function in individuals post TBI (S. H. Chen et al., 1997; O'Neil-Pirozzi & Hsu, 2016; L. E. Powell et al., 2019).

KEY POINTS

- Computer assisted rehabilitation and computer software programs (BrainHQ, ProSolv) may not be effective at improving executive function in patients post TBI.

Virtual Reality

Virtual reality (VR) technology generates artificial dynamic environments with sensory properties, and it has been used as a rehabilitation tool for individuals with ABI, as it facilitates task repetition and real-time feedback (Alashram, Annino, Padua, Romagnoli, & Mercuri, 2019). VR allows individuals to interact with and experience a virtual environment in three-dimensions, realistically simulating different situations, environments, and tasks through immersive (head-mounted display) or non-immersive (computer monitor or projector screen) multimedia (Sisto, Forrest, & Glendinning, 2002). In addition, VR systems provide the option to adjust the task complexity according to individual skills and goals (Brassel, Power, Campbell, Brunner, & Togher, 2021). VR systems are constantly evolving, providing a safe and motivating environment for practicing real life scenarios (Shin & Kim, 2015).

TABLE 13 | The Effect of Virtual Reality Rehabilitation Programs on Executive Function Post ABI

Author, Year Country Study Design Sample Size	Methods	Outcome
Jacoby et al. (2013) Israel RCT PEDro=7 N=12	**Population:** TBI; *Experimental group (EG; n=6)*: Mean Age=27.83yr; Gender: Male=4, Female=2; Mean Time Post Injury=126d; Mean GCS=8. *Control group (CG; n=6)*: Mean Age=30.67yr; Gender: Male=4, Female=2; Mean Time Post Injury=100d; Mean GCS=6.25. **Intervention:** Participants were randomly assigned to the EG group or the CG group. All participants in the EG received 10 sessions of virtual reality (VR) training (45 min/session, 3-4 d/wk). The CG received general cognitive re-training treatment identical in length and duration to the EG. **Outcome Measures:** Multiple Errands Test – Simplified Version (MET-SV), Executive Function Performance Test (EFPT).	1. Participants in the EG group improved more in their final scores on the MET-SV relative to their initial scores compared to the CG group (p=.046). 2. Participants in the EG improved more in their final scores on the EFPT relative to their initial scores compared to the CG (p=.046). 3. Between group differences showed no significant difference at baseline.
Man et al. (2013) Hong Kong RCT PEDro=4 N=40	**Population:** TBI. Age Range=18-55yr; Gender: Unspecified; Time Post Injury: Unspecified; Mean GCS=10. **Intervention:** Participants received twelve 20-25min sessions of a vocational problem-solving skill training program. Participants were randomized to either artificial intelligence virtual reality (treatment group, TG) or conventional psychoeducation (control group, CG). Outcomes were assessed before and after treatment, and at follow-up of 1, 3, and 6mo. **Outcome Measures:** Wisconsin Card Sorting Test (WCST), Tower of London Test (TLT), Vocational Cognitive Rating Scale (VCRS), Self-efficacy (SE), Vocational outcomes.	1. Both groups showed significant improvements on WCST, TLT, VCRS, SE, and vocational outcomes after treatment compared to baseline ($p<.05$). 2. On WCST, the TG performed better than the CG after treatment ($p\leq.02$). No other significant between-group differences were found.
Dahdah et al. (2017) USA	**Population:** CVA=6, TBI=5, Tumor=2, Anoxia brain injury=2; Mean Age=40.3yr; Gender: Male=12, Female=3.	1. No statistically significant performance differences were found from baseline to

Pre-Post $N_{Initial}$=21 N_{Final}=15	**Intervention:** Participants received the virtual reality (VR) intervention sessions (apartment and classroom) twice per week for a 4wk period. Sessions 1 and 8 included all types of distractors, sessions 2 and 3 included no distracting stimuli, sessions 4 and 5 included only auditory distracting stimuli, and sessions 6 and 7 included only visual distracting stimuli. **Outcome Measure:** Woodcock-Johnson, 3rd edition (WJ-III pair cancellation subtest), Delis-Kaplan Executive Function System (D-KEFS Color-Word Interference subtest), Automated Neuropsychological Assessment Metrics (ANAM Go/No-Go and unimodal Stroop subtests), VR Stroop task (apartment and classroom).	conclusion of the study for the VR apartment Stroop or D-KEFS Stroop test. 2. For the VR classroom, participants' shortest response time on the word-reading condition was significantly reduced by session 8 (p=.04). All other VR classroom Stroop variables did not show significant differences. 3. No significant differences from session 1 to session 8 were found for all pair cancellation subtest scores. 4. From session 1 to 8, the ANAM Stroop word-reading percentage of items with a correct response (p=.03), ANAM Stroop word-reading number of correct responses per minute (p=.03), and ANAM Go/No-Go number of impulsive/bad responses (p=.04) significantly increased. All other ANAM variables did not show significant differences.

Discussion

With the development of technology, VR has gained traction as an effective tool for the rehabilitation of cognitive functions, and it has been used to enhance cognition in individuals with stroke, dementia, multiple sclerosis, Parkinson's disease and TBI (Maggio et al., 2019). Two RCTs examined the effect of a virtual environment on executive functioning in individuals with TBI (Jacoby et al., 2013; Man et al., 2013). Man et al. (2013) focused on vocational problem-solving skills and identified significant improvements in both VR intervention and conventional psychoeducation control groups; however, there were no significant between-group differences for cognitive or vocational outcomes except on WCST percent errors and percent conceptual level response (Man et al., 2013). Conversely, Jacoby et al (2013) found that participants receiving virtual reality training improved more on multi-tasking measures and executive function when compared to the control group who received general cognitive re-training treatment.

In a pre-post study, Dahdah et al. (2017) investigated virtual reality interventions in a mixed ABI population. The researchers found that repetition of the Stroop test in different virtual reality environments showed limited improvement in performance on those specific tests (Dahdah et al., 2017). Given that mixed results were reported on the efficacy of virtual reality training post ABI, it is difficult to make a conclusive decision on what aspects of executive functioning virtual reality benefits, and to what degree.

Conclusions

There is level 1b evidence that virtual-reality training is not superior to conventional cognitive training at improving executive function outcomes post TBI (Dahdah et al., 2017; Jacoby et al., 2013; Man et al., 2013).

KEY POINTS

- Virtual reality does not likely improve executive functioning following an ABI.

Mobile Technology

Smartphones are already designed to send notifications about their use, as well as multiple companies design apps for each phone brand interface allowing individuals to keep their current devices and still access helpful applications. Smartphones are accessible and acceptable devices for individuals with TBI, as they provide valuable organizational aids and other functions (Wong, Sinclair, Seabrook, McKay, & Ponsford, 2017).

TABLE 14 | The Effect of Mobile Technology use on Executive Function Post ABI

Author, Year Country Study Design Sample Size	Methods	Outcome
Elbogen et al., (2019) USA RCT PEDro=8 $N_{Initial}$=112, N_{Final}=89	**Population:** TBI=64; *Treatment Group (n=57):* Mean Age=36.77±8.60yr; Gender: Male=43, Female=4; Mean Time Post Injury= Not Reported; Severity: Mild=22, Moderate-to-Severe=35. *Control Group (n=55):* Mean Age=36.25±8.30yr; Gender: Male=50, Female=5; Mean Time Post Injury=Not Reported; Severity: Mild=, Moderate-to-Severe=29. **Intervention:** Participants were randomized to receive cognitive rehabilitation with a novel program – Cognitive Applications for Life Management (CALM; Treatment Group) or psychoeducation on TBI (Control Group). The program focuses on goal management and brain health training utilizing mobile technology and social support. Participants completed three 60-90min sessions at 0, 2 and 4mo. Outcome measures were assessed at baseline and 6mo post randomization. **Outcome Measures:** Delis-Kaplan Executive Dysfunction System (DKEFS), Barratt Impulsiveness Scale (BIS), Dimensions of Anger Reactions (DAR), Head Injury Behaviour Scale (HIBS), Clinician Administered Posttraumatic Stress Disorder Scale (CAPS).	1. No significant improvements were observed in measures of executive function (DKEFS; $p>0.05$) or impulsiveness (BIS; $p>0.05$) with the CALM intervention at 6mo. 2. Significant improvements in measures of emotion (DAR; $p<0.05$) and behavioural regulation (HIBS; $p<0.05$) were observed with the CALM intervention at 6mo. 3. Participants receiving calm reported a 25% decrease in anger compared to 8% in the control group at 6mo ($p=0.008$). 4. Family/friends of participants reported that participants receiving the CALM intervention had 26% fewer maladaptive interpersonal behaviours than 6% of those in the control group at 6mo ($p=0.016$). 5. Symptoms of PTSD significantly reduced in participants that were randomized to CALM ($p<0.01$).
Powell et al. (2019) USA RCT	**Population:** TBI=17, Stroke/aneurysm=4, Other=6, More than 1 brain injury=3; Mean Age=44 yr; Gender: Male=11, Female=12; Mean Time Post Injury=4 yr.	3. No significant differences between groups were found for knowledge test, PSQ clear thinking, PSQ emotional self-regulation, TBI-SE, or SWLS.

PEDro=4 N=23	**Treatment:** Coaches were randomly assigned to ProSolv intervention or usual care. Participants new to the outpatient rehabilitation program were randomized to coaches and clients already working with coaches were offered the opportunity to participate in the study with that coach. In six 1 h sessions over 8wk, ProSolv group (n=14) received training on using ProSolv app and Usual Care group (n=9) received usual care including training in goal planning/management, time pressure management, and problem-solving skills. ProSolv group had access to the ProSolv app outside of the sessions as a resource for remembering steps to effective problem solving and creating personalized problem-solution lists. **Outcome Measure:** Project-specific knowledge test, Problem Solving Questionnaire (PSQ clear thinking and emotional self-regulation subscales), Problem Solving Rating Scale (PSRS), TBI Self-Efficacy Questionnaire (TBI-SE), Satisfaction with Life Scale (SWLS), System Usability Scale (SUS).	4. The average SUS score reported at post-test was 3.5 for the tutorial and 3.6 for the app, suggesting that on average, ProSolv participants were slightly higher than neutral on whether the program components were usable.
Gracey et al. (2017) UK RCT PEDro=6 $N_{Initial}$=74, N_{Final}=59	**Population:** CVA=23, Infection=3, TBI=33, Tumor=10, Missing=1. *Control First (n=34)*: Mean Age=50.18yr; Gender: Male=23, Female=11; Mean Time Post Injury=8.62yr. *Assisted Intention Monitoring (AIM, n=36)*: Mean Age=46.36yr; Gender: males=23, females=13; Mean Time Post Injury=4.89yr. **Intervention:** Participants were randomized to receive AIM or control first. In the AIM-first group, participants received goal management training followed by text messages for improving achievement of everyday intentions. Control-first group received brain injury information, Tetris game, and non-informational text messages. After 3wk, participants were crossed over with AIM-first group receiving usual care and control-first group receiving AIM. **Outcome Measures:** Mean daily proportion of intentions achieved, Achievement of all goals excluding the phone call task, Profile of Mood States total mood disturbance (POMS MD), Hotel Task, Verbal Fluency.	5. Participants achieved a greater proportion of intentions during the AIM intervention relative to control (p=.040). 6. Participants achieved a greater proportion of goal attainment (without the phone call task) during the AIM intervention relative to control (p=.033). 7. No significant Group x Time interaction effect was found for the POMS MD or Hotel Test. When only comparing group differences at post-intervention phase 1, intention to treat analysis showed no significant difference between groups for proportion of intentions achieved or achievement of goals excluding the phone task.

Discussion

Elbogen et al. (2019) randomized participants, including an individual with TBI and a caregiver, to two different groups. One group received the Cognitive Application for Life Management (CALM) intervention, including goal management training (GMT) and the use of mobile devices. A different group received Brain Health Training, including psychoeducation and mobile devices. Results indicated negative findings related to executive dysfunction in participants; however, the CALM group reported a 25% decrease in anger when compared to 8% in the control group (Elbogen et al., 2019).

Powell et al. (2019) implemented a problem-strategy training intervention using ProSolv, an application that can be used on a smartphone and/or a computer with internet access. The BRIEF-A scale was used to assess executive function; however, no statistically significant results were reported (L. E. Powell et al., 2019). Similar results were reported by Gracey et al. (2017), who examined the effectiveness of pairing a brief goal-directed rehabilitation with SMS text messages for individuals with ABI. These alerts were designed to improve executive monitoring of intentions. The authors found that, while the intervention was effective in achieving daily intentions, no statistically significant differences were found on tests of executive functioning (Gracey et al., 2017).

Conclusions

There is level 1b evidence that a Cognitive Application for Life Management (CALM) intervention, that involves both goal management training (GMT) and the use of mobile devices may not be effective in treating executive dysfunction in individuals with TBI (Elbogen et al., 2019).

There is level 2 evidence that the ProSolv mobile application may not improve executive functioning in individuals with ABI (L. E. Powell et al., 2019).

There is level 1b evidence that pairing a brief-goal directed rehabilitation with SMS text messages may not be effective in enhancing executive function in individuals with ABI (Gracey et al., 2017).

KEY POINTS

- A Cognitive Application for Life Management (CALM) intervention may not be effective in treating executive dysfunction in individuals post TBI.
- The ProSolv mobile application may not improve executive function in individuals with ABI.
- Combining a brief goal-directed rehabilitation with SMS text message alerts may not improve executive function in individuals with ABI.

Repetitive Transcranial Magnetic Stimulation (rTMS)

Repetitive Transcranial Magnetic Stimulation (rTMS) is used as a diagnostic tool to explore changes in cortical excitability. rTMS has relevant therapeutic application for individuals with TBI and can potentially improve some cognitive symptoms in this population (Castel-Lacanal et al., 2014).

TABLE 15 | The Effect of rTMS on Executive Function Post TBI

Author, Year Country Study Design Sample Size	Methods	Outcome
Neville et al. (2019) Brazil RCT PEDro=9 $N_{Initial}$=36, N_{Final}=30	**Population:** TBI (Diffuse Axonal Injury). Experimental Group (n=17): Gender: Male=15, Female=2; Mean Age=32.62±12.8yr; Mean GCS=5.0±3.0. Control Group (n=13): Gender: Male=12, Female=1; Mean Age=29.0±10.4yr; Mean GCS=4.4±2.5. **Interventions:** Individuals were randomized to receive 10 sessions of either repetitive transcranial magnetic stimulation (rTMS) or sham stimulation. Neuropsychological evaluations were performed at baseline, post treatment and at 90d post treatment. **Outcome Measure:** Trail Making Test (TMT) A & B, Controlled Oral Word Association Test, Stroop Test, Five-Point Test, Digit Span Test (Forwards & Backwards), Symbol Digit Test, Hopkins Verbal Learning Test, Brief Visuospatial Memory Test, Grooved Pegboard Test.	1. No significant group, time or group by time interactions were found for executive function, attention, memory, or motor function, except for a significant effect due to time for executive function ($p<0.001$) 2. Between-group comparisons of performance on TMT Part B at baseline and after the 10th rTMS session did not differ between groups ($p=0.680$, $p=0.341$, respectively). 3. Within group comparisons showed a significant difference in only the sham group on the TMT-B, showing improvement in performance ($p=0.023$). 4. No significant differences were observed on any neuropsychological tests. 5. No serious adverse events were reported. There was a higher frequency of mild adverse events in the rTMS group than sham, but it was not significant.

Discussion

Only one study evaluated the effects of rTMS on executive function; however, no significant improvements were observed between the intervention group and the sham group (Neville et al., 2019). The effectiveness of rTMS on executive functioning in individuals with TBI needs to be further explored.

Conclusions

There is level 1b evidence that rTMS may not enhance executive functioning in individuals with TBI (Neville et al., 2019).

KEY POINTS

- rTMS may not improve executive function in individuals with TBI. More studies are needed to further explore the effectiveness of this brain stimulation technique.

Emotional Regulation

Emotional regulation involves the capacity of the individual to modulate and control their subjective experience and expression of emotions, as well as reducing emotional arousal; additionally, emotional regulation is a relevant aspect of executive function (Stubberud, Løvstad, Solbakk, Schanke, & Tornås, 2020). Individuals with TBI, particularly those with more severe injuries, often experience difficulties with emotional regulation, such as apathy and disinhibition (McDonald & Genova, 2021).

TABLE 16| The Effect of Emotional Regulation Therapy on Executive Function Post ABI

Author, Year Country Study Design Sample Size	Methods	Outcome
Cantor et al. (2014) USA RCT PEDro=6 N=98	**Population:** TBI; Mean Age=45.3 yr; Gender: Male=37, Female=61; Mean Time Post Injury=12.6 yr; Severity: Mild=49, Moderate=19, Severe=30. **Intervention:** Participants were randomly assigned to either immediate start (IS; n=49) or waitlist control (WL; n=49) groups. Participants received group sessions of emotional regulation (2 sessions, 45 min) and an individual problem-solving session of attention training (1 session, 60 min) per day (3 days/wk for 12 weeks). Group sizes were generally 4-6 participants. **Outcome Measure:** Attention Rating and Monitoring Scale (ARMS), Behavioural Assessment of the Dysexecutive Syndrome, Difficulties in Emotion Regulation Scale (DERS), Executive Function Composite from Factor Analysis (EF index), Problem Solving Inventory (PSI), Frontal System Behavioural Scale (FrSBe).	1. There was a significant treatment effect for the EF index favoring the IS group (p=0.008). 2. There was no significant difference between groups in the DERS of ARMS. 3. Secondary analysis revealed a significant treatment effect for the FeSBe scale (p=0.049) and the PSI (p=0.016). 4. There were no other significant treatment effects. Variance of depression, age, severity, and time since injury did not change treatment effects.
Rath et al. (2003) USA RCT PEDro=2 N=46	**Population:** TBI: Mean Age=43.6 yr; Gender: Male=23, Female=37; Mean Time Post Injury=48.2 mo. **Intervention:** Participants were randomized into the innovative (n=32) or conventional (n=28) treatment groups. The innovative group received 24, 2 hr sessions focusing on emotional self-regulation and clear thinking. The conventional group received 24, 2-3 hr sessions focusing on cognitive remediation and psychosocial groups. **Outcome Measure:** Weinberg Visual Cancellation Test, Stroop Color–Word Task, FAS—Controlled Oral Word Association Test, Will-Temperament Scale, Visual Reproduction, Immediate and Delayed recall, Watson-Glaser Critical Thinking Appraisal, Wechsler Adult Intelligence Scale—III.	1. The innovative group showed significant improvements in visual memory immediate recall (p<0.001). 2. The conventional and the innovative group showed significant improvements: on logical memory recall (p<0.001), logical memory delayed recall (p=0.010), and visual memory delayed recall (p=0.010). 3. The conventional group had significant improvements in reasoning (p<0.050). 4. The innovative group had significant improvements in executive function (p<0.050); problem-solving self-appraisal (p=0.005); self-appraised clear thinking and emotional self-regulation (p<0.010); and observer ratings of roleplayed scenarios (p<0.005).

Discussion

Emotional regulation has been examined as a potential intervention for the remediation of executive dysfunction post ABI (Cantor et al., 2014; Rath et al., 2003). Cantor et al. (2014) found that an emotional regulation intervention resulted in significant improvements on executive function (EF, FeSBe, PSI) in individuals with TBI (Cantor et al., 2014).

Rath et al. (2003) compared two cognitive rehabilitation therapies: conventional (cognitive remediation and psychosocial components) versus an innovative rehabilitation approach focusing on emotional self-regulation and clear thinking. Outcomes were assessed with measures such as executive function, problem-solving self-appraisal, self-appraisal clear thinking and emotional regulation, and observer ratings of role-played problem-solving scenarios across multiple domains of cognition including attention, memory, reasoning, psychosocial functioning, and problem-solving measures. Participants in the innovative group showed significant improvements in problem-solving, comparing baseline to post intervention outcomes, and improvements were maintained at the 6-month follow-up (Rath et al., 2003).

Conclusions

There is level 1b evidence that emotional regulation interventions are effective at improving executive function in individuals with TBI (Cantor et al., 2014; Rath et al., 2003).

KEY POINTS

- Emotional regulation interventions may improve executive function in individuals with TBI.

Pharmacological Interventions

Donepezil

Donepezil is a centrally acting acetylcholinesterase inhibitor that has been used in the treatment of Alzheimer's disease (AD) and dementia, as well as to enhance cognitive functions in individuals with TBI (Traeger, Hoffman, Misencik, Hoffer, & Makii, 2020). Donepezil has been used to enhance cognitive functions such as processing speed, memory, attention, awareness and functional ability in individuals with TBI (Swenson, Roehmer, Tran, & Plummer, 2021).

TABLE 17 | The Effect of Donepezil on Executive Function Post ABI

Author, Year Country Study Design Sample Size	Methods	Outcome
Khateb et al. (2005) Switzerland Pre-Post $N_{initial}$=15, N_{final}=10	**Population:** TBI; Mean age=43 yr; Gender: Male=8, Female=7; Mean Time Post Injury=4 2mo. **Intervention:** Participants were administered donepezil 5 mg/day for 1 mo, followed by 10 mg/day for 2 months. **Outcome Measure:** Stroop test, Trail Making Test (TMT), Rey Auditory Verbal Memory Test (RAVMT), Test for Attentional Performance (TAP).	1. Four of 15 participants stopped due to side effects within the first week (e.g., nausea, sleep disorders, anxiety, dizziness, etc.). 2. Changes on the neuropsychological evaluation show modest improvement. However, the comparison of the global score of all questionnaires before and after therapy was not significant (p=0.058). 3. A significant improvement in executive function was only found for the Stroop Colour naming test (87.3±22.9 to 79.5±19.1, p=0.030); the RAVMT-learning for learning and memory (47.7±6.9 to 53.5±5.0, p=0.050); and the errors subsection of divided attention for attention, (5.8±3.3 to 2.9±2.7, p=0.030).

Discussion

Khateb et al. (2005) investigated the effects of donepezil on cognition in individuals with TBI. The authors found that treatment with Donepezil improved executive function in individuals with TBI, as the results from the Stroop-colour naming test showed significant improvements ($p<0.030$). Donepezil was found to be effective in improving executive function; however, possible benefits of donepezil administration must be balanced against the observed side effects in 27% of the population. Additionally, variability in TBI pathology may result in a variation in neurochemical brain changes, leading to different responses in individuals treated with donepezil (Florentino, Mohammad, & Ma, 2022). Further randomized control trials are required to better explore the efficacy of donepezil post TBI.

Conclusions

There is level 4 evidence that donepezil is effective in improving executive function in individuals post TBI (Khateb et al., 2005).

KEY POINT

- Donepezil may improve executive function in individuals with TBI.

Methylphenidate

Methylphenidate is a central nervous stimulant that increases the synaptic and extracellular concentrations of dopamine (Barnett & Reid, 2020). This medication has been used to treat Attention Deficit Hyperactivity Disorder in adults and children (Cândido, Menezes de Padua, Golder, & Junqueira, 2021), as well as to treat mental fatigue and to help improve cognitive function in individuals with TBI (Johansson, Wentzel, Andrell, Ronnback, & Mannheimer, 2017; Levin et al., 2019).

TABLE 18 | The Effect of Methylphenidate on Executive Function Post TBI

Author, Year Country Study Design Sample Size	Methods	Outcome
Jenkins et al., (2019) UK RCT Crossover PEDro=9 $N_{Initial}$=46, N_{Final}=40	**Population:** TBI=40; *Treatment Group (Intervention First; n=20):* Mean Age= 40±12yr; Gender: Male=18, Female=2; Mean Time Post Injury=67±85mo; Severity: Mean GCS=8.3±5.2. *Control Group (Placebo First; n=20):* Mean Age=39±12yr; Gender: Male=16, Female=4; Mean Time Post Injury=67±85mo; Severity: Mean GCS=8.3±5.4. **Intervention:** Participants were randomized to receive 0.3mg/kg of methylphenidate (treatment group) twice a day for 2wk with crossover to placebo (control group) twice a day for 2wk and vice versa. Outcome measures were assessed at baseline, 2 and 4wk. **Outcome Measures:** Choice Reaction Time (CRT) Task, Single-Photon Emission Computed Tomography (SPECT), Trail Making Test (TMT), Stroop Test, People Test, Wechsler Abbreviated Scale for Intelligence (WASI), Lille Apathy Rating Scale (LARS), Visual Analogue Scale for Fatigue (VAS-F), Glasgow Outcome Scale-Extended (GOSE), Hospital Anxiety and Depression Scale (HADS), Frontal Systems Behaviour Scale (FrSBe), Cognitive Failures Questionnaire, Rating Scale of Attentional Behaviour.	1. No significant differences (p>0.05) were observed between groups on several measures: • TMT • Stroop • People Test • WASI • FrSBe • GOSE • HADS • Cognitive Failures Questionnaire • Rating Scale of Attentional Behaviour 2. Using SPECT imaging, participants were divided into groups with low and normal dopamine transporter levels for analysis. 3. Participants with low dopamine transporter levels receiving methylphenidate significantly improved on several measures when compared to controls: • CRT (p=0.02) • LARS self-reported (p=0.03) and caregiver (p=0.02) • VAS-F (p=0.007) 4. Participants with normal dopamine transporter levels receiving methylphenidate reported significantly less fatigue when compared to controls (VAS-F, p=0.03).
Dymowski et al. (2017) Australia RCT PEDro=9 $N_{Initial}$=11, N_{Final}=10	**Population:** TBI. *Methylphenidate Group (n=6)*: Mean Age=35 yr; Gender: Male=4, Female=2; Mean Time Post Injury=366 d; Mean Worst GCS=4.83. *Placebo Group (n=4)*: Mean Age=32.5 yr; Gender: Male=2, Female=2; Mean Time Post Injury=183.5 d; Mean Worst GCS=4.50. **Treatment:** Participants were randomly assigned to receive either methylphenidate (0.6 mg/kg/d rounded	1. After applying Bonferroni corrections, no significant differences between groups from baseline to 7 wk, baseline to 8 wk, or baseline to 9 mo were observed for SDMT, TMT A, TMT B, Hayling A, Hayling B, Hayling error, DS Forward, DS Backward, DS Sequencing, DS Total, 2&7 ASRS, 2&7 CSRS,

Author, Year Country Study Design Sample Size	Methods	Outcome
	to the nearest 5mg with maximum daily dose of 60 mg) or placebo (lactose). Outcomes relating to processing speed, complex attentional functioning, and everyday attentional behaviour were assessed at baseline, 7 wk (on-drug), 8 wk (off-drug), and 9 mo follow-up. **Outcome Measures:** Symbol Digit Modalities Test (SDMT), Trail Making Test (TMT) A and B; Hayling (A, B, error), Digit Span (DS-Forward, Backward, Sequencing, Total), Ruff 2&7 Selective Attention Test Automatic Speed Raw Score (2&7 ASRS), Ruff 2&7 Selective Attention Test Controlled Speed Raw Score (2&7 CSRS), Simple Selective Attention Task Reaction Time (SSAT RT), Complex Selective Attention Task Reaction Time (CSAT RT), N-back 0-back RT, N-back 1-back RT, N-back 2-back RT, Rating Scale of Attentional Behaviour Significant Other (RSAB SO).	SSAT RT, CSAT RT, N-back 0-back RT, N-back 1-back RT, N-back 2-back RT, or RSAB SO.
Speech et al. (1993) USA RCT PEDro=7 N=12	**Population:** TBI; Mean Age=27.6 yr; Gender: Male=5, Female=7; Mean Time Post Injury=48.5 mo. **Intervention:** In a crossover design, participants were randomly assigned to receive 0.3 mg/kg methylphenidate, 2×/d, for 1 wk, followed by 1wk of placebo, or receive the treatment in a reverse order. **Outcome Measures:** Gordon Diagnostic System, Digit Symbol, and Digit Span subtests of the Wechsler Adult Intelligence Scale-Revised, Stroop Interference Task, Sternberg High Speed Scanning Task, Selective Reminding Test, Serial Digit Test, and Katz Adjustment Scale.	1. No significant differences were found between methylphenidate and placebo condition in any of the outcome measures studied.
Al-Adawi et al. (2020) Oman Pre-Post $N_{Initial}$=32, N_{Final}=24	**Population:** TBI=32; Age Range 18-25yr=17, Age Range 26-35yr=7; Gender: Male=13, Female=11; Time Post Injury: Acute(<2mo) =9, Chronic (≥2mo) =15; Severity: Mild=5, Moderate=15, Severe=1. **Intervention:** Participants received methylphenidate starting at a dose of 5mg/d, increasing to a dose of 10mg/d for 30 days. Outcome measures were assessed at baseline, 15d prior to the initiation of methylphenidate, 30d and follow-up at 15 and 30d. **Outcome Measures:** Digit Span, Verbal Fluency, Hospital Anxiety and Depression Scale (HADS).	1. Methylphenidate significantly improved measures of executive functioning (Digit Span and Verbal Fluency) from baseline to 30 days ($p<0.001$) and post withdrawal (Digit Span, $p<0.001$; Verbal Fluency, $p=0.008$). 2. Affective measures did not significantly improve from baseline to 30 days or post-withdrawal from methylphenidate (HADS, $p>0.05$). 3. No significant differences were observed between genders on executive functioning or affective measures with methylphenidate ($p>0.05$).

Discussion

Jenkins et al. (2019) found that the cognitive effects of methylphenidate were only exhibited by individuals with low caudate dopamine transporter levels; however, no significant results were reported in executive function measures. Dymowski et al. (2017) investigated the effects of short-term, 7-week,

methylphenidate administration in individuals with TBI compared to a placebo control group. There was no significant improvement, or difference between groups for various measures and tests of cognition, including executive function. Speech et al. (1993) conducted a double blind placebo controlled trial evaluating the effects of methylphenidate following closed head injury and arrived at similar conclusions, as the treatment and placebo group did not vary in any neurobehavioral measures. Only one study by Al-Adawi et al. (2020), with a pre-post design, found that short term use of methylphenidate significantly improved measures of executive functioning in individuals with TBI.

Conclusions

There is level 1a evidence that methylphenidate may not be effective, compared to placebo for the improvement of executive functioning following TBI (Al-Adawi et al., 2020; Dymowski et al., 2017; P. O. Jenkins et al., 2019; Speech et al., 1993).

KEY POINTS

- Methylphenidate likely does not improve executive function in individuals with TBI.

Sertraline

Sertraline is a selective serotonin reuptake inhibitor (SSRI) that has been used for the treatment of major depressive disorder, panic disorder, obsessive-compulsive disorder and post-traumatic stress disorder (DeVane, Liston, & Markowitz, 2002). Sertraline has been used to treat depression in individuals with TBI, and has the best quality evidence in reduction of depressive symptoms (Narapareddy et al., 2020). However, some studies have shifted focus and begun to evaluate the benefits of sertraline at improving cognitive disorders (Banos et al., 2010).

TABLE 19 | The Effect of Sertraline on Executive Function Post ABI

Author Year Country Study Design Sample Size	Methods	Outcome
Banos et al. (2010) USA RCT PEDro=9 N=99	**Population:** TBI. *Treatment group (n=49)*: Gender: Male=39, Female=10; Mean Age=35.3 yr; Mean Time Post Injury=21.5 d; Mean GCS=5.8. *Placebo group (n=50):* Gender: Male=33, Female=17; Mean Age=34.5 yr; Mean Time Post Injury=19.2 d; Mean GCS=5.8. **Intervention:** Participants were randomized to either the treatment group which took sertraline daily (50	1. More subjects in the treatment group dropped out at each time point. 2. Those in the placebo groups at the 6th and 12th month assessment period were older than the control group and had higher GCS. 3. Overall, there were no significant differences between the two groups on any of the cognitive measures.

Author Year Country Study Design Sample Size	Methods	Outcome
	mg) or placebo. Participants were assessed at 3, 6 and 12 months. **Outcome Measure:** Wechsler Memory Index (Wechsler Adult Intelligence Scale III), Symbol-Digit Modalities Test, Logical Memory, Trial Making Test and 64-item Wisconsin Card Sorting Test.	

Discussion

The effect of early administration of sertraline on cognitive functioning was evaluated by Banos et al. (2010) in an RCT. When comparing the sertraline group, who received 50 mg per day, to a control group (placebo), there were no significant between group differences on any of the neuropsychological tests. Executive function was not found to improve following the administration of sertraline. It should be noted that more participants in the sertraline group dropped out of the study compared to the control group, which may be in part due to the potential side effects associated with the treatment. Sertraline has been associated with several side effects, including agitation/anxiety, constipation, diarrhoea, dry mouth, insomnia, nausea, and sleepiness/drowsiness (Cipriani et al., 2010).

Conclusions

There is level 1b evidence that sertraline does not improve executive function, compared to placebo, in individuals who have sustained a moderate to severe TBI (Banos et al., 2010).

KEY POINT

- Sertraline may not improve executive function and may be associated with several side effects.

Amantadine

Amantadine is an antagonist of N-methyl-D-aspartate receptors and an agonist of the dopaminergic system (Liepert, 2016), and it is also considered to work pre- and post-synaptically by increasing the amount of dopamine in the synapse (Napolitano, Elovic, & Qureshi, 2005). Amantadine has been used to treat dyskinesia in Parkinson's disease and to facilitate cognitive recovery in individuals with TBI (Loggini et al., 2020).

TABLE 20 | The Effect of Amantadine on Executive Function Post ABI

Author Year Country Study Design Sample Size	Methods	Outcome
Schneider et al. (1999) USA RCT Cross-over PEDro=5 N=10	**Population:** TBI; Mean Age=31 yr; Gender: Male=7, Female=3; GCS Score Range=3-11. **Intervention:** Participants were randomized to either amantadine (50-150 mg 2 x/d) or placebo for 2 wk in a crossover design with a 2 wk washout period. **Outcome Measure:** Battery of Neuropsychological tests: Galveston Orientation and Amnesia Test, Rivermead Behavioural Memory Test (RBMT), Trail Making Test Form A, Digit Span Forward, Visual Memory Span Forwards, Mental Control Total Score, Digit Span Backwards, Visual Memory Span Backwards, Trail Making Test Form B, Controlled Oral Word Association Test. Neurobehavioural Rating Scale Subtests for inattention, disinhibition, memory deficit and agitation.	1. There was a general trend towards improvement in the study sample over the 6 wk. 2. There were no significant between group differences in terms of orientation (p=0.062), attention (p=0.325), memory (p=0.341), executive flexibility (p=0.732) or behaviour (p=0.737). 3. There was no significant difference for participants receiving amantadine versus participants receiving placebo
Kraus et al. (2005) USA Pre-Post N=22	**Population:** TBI; Mean Age=36 yr; Gender: Male=17, Female=5; Severity of Injury: Mild=6, Moderate=6, Severe=10; Mean Time Post Injury=63.2 mo. **Intervention:** Positron emission tomography (PET) scan was done, and participants received amantadine (10 0mg titrated to up to 400 mg/d over 3 wk). Amantadine was administered 3×/d (200 mg at 8AM, 100 mg at 12PM, and 100mg at 4PM) for 12 wk. **Outcome Measure:** Trail Making Test Part A and B (TMT A, TMT B), Controlled Oral Word Association Test (COWAT), Digit Span, California Verbal Learning Test (CVLT), Rey Osterreith Complex Figure-Immediate (Rey Im) and Delayed (Rey De) recall.	1. Measures of executive function, as indicated by TMT B and COWAT, were significantly improved in participant following treatment with amantadine (t=-2.47; p<0.020). 2. No significant differences were found for attention (TMT A and Digit Span) or memory (CVLT, Rey Im, and Rey De). 3. Correlational analyses with PET scan suggest that there may be a strong relationship between executive domain improvement and changes in left pre-frontal metabolism (r=0.92; p=0.010) and left medial temporal metabolism (r=0.91; p=0.010).

Discussion

Schneider et al. (1999) administered amantadine or placebo to participants for 2 weeks, followed by a 2-week washout, and 2 weeks of the alternative (amantadine or placebo). Neurobehavioral and neuropsychological outcomes were assessed, including executive function (Trail Making Test Form B, Controlled Oral Word Association Test). The authors did not find any significant difference for amantadine versus placebo in individuals with TBI. Kraus et al. (2005) found different findings in a pre-post-study. The authors used an open-label design and administered 400 mg of amantadine per day, over three weeks, to individuals with TBI. Significant improvements were observed on test of executive function. Both studies had small sample sizes and more research, particularly RCTs, are needed in this area.

Conclusions

There is level 1b evidence that Amantadine may not help to improve executive functioning in individuals with TBI compared to placebo (Schneider et al., 1999); however, more studies are needed.

KEY POINT

- The evidence on the effectiveness of Amantadine in improving executive function is unclear. Further studies are needed.

Bromocriptine

Bromocriptine is a dopaminergic agonist which primarily exerts its actions through binding and activating D_2 receptors (Whyte et al., 2008). It has been suggested that dopamine is an important neurotransmitter for prefrontal function, an important area of the brain that contributes to cognitive function, memory, intelligence, language, and visual interpretation (McDowell et al., 1998; Siddiqui, Chatterjee, Kumar, Siddiqui, & Goyal, 2008). Dopamine agonists such as Bromocriptine have been used to treat individuals with TBI that present with minimally conscious state (Passler & Riggs, 2001), as well as to facilitate cognitive recovery and rehabilitation in this population (Frenette et al., 2012).

TABLE 21 | The Effect of Bromocriptine on Executive Function Post TBI

Author Year Country Study Design Sample Size	Methods	Outcome
McDowell et al. (1998) USA RCT PEDro=4 N=24	**Population:** TBI; Median Age=32.5 yr; Gender: Male=20, Female=4; GCS Range=3-8; Time Post injury Range=27 d-300 mo. **Intervention:** In a crossover design, participants were randomly assigned to receive bromocriptine (2.5 mg) then placebo or receive treatment in the reverse order. **Outcome Measure:** Dual-task Paradigm (counting and digit span), Stroop Test, Spatial Delayed-response Task, Wisconsin Card Sorting Test (WCST), Reading Span Test, Trail Making Test (TMT), Controlled Oral Word Association Test (COWAT), and Control Tasks.	1. Following bromocriptine treatment there were significant improvements on the dual-task counting ($p=0.028$), dual-task digit span ($p=0.016$), TMT ($p=0.013$), Stroop Test ($p=0.050$), COWAT ($p=0.020$), and WCST ($p=0.041$). 2. Bromocriptine had no significant effects on working memory (e.g., spatial delayed-response task and reading span test; $p=0.978$), or on control tasks ($p=0.095$).
Powell et al. (1996) UK Case Series N=11	**Population:** TBI=8, SAH=3; Mean Age=36 yr; Gender: Male=6, Female=5; Time Post Injury Range=2mo-5 yr. **Intervention:** Patients received bromocriptine (a maximum dose of 5-10 mg/d). Patient assessments included two baseline evaluations (BL1 and BL2), evaluation when stabilized at maximum bromocriptine dose (MAXBROMO), and two post withdrawal evaluations (POST1 and POST2). **Outcome Measure:** Percentage Participation index (PPI), Spontaneity, Motivation, Card Arranging Reward Responsivity Objective Test (CARROT), Digit Span, Buschke Selective Reminding Test (BSRT), Verbal Fluency, Hospital Anxiety and Depression Scale.	1. Reported PPI ($p<0.0001$), motivation, and spontaneity (both $p<0.005$) increased significantly from BL2 to MAXBROMO. Improvements were seen in CARROT as well ($p<0.0001$). 2. Significant improvements were observed from BL2 to MAXBROMO on the digit span ($p<0.001$), BSRT ($p<0.01$), and verbal fluency ($p<0.001$). Scores on all three tests decreased (non-significant) from MAXBROMO to POST1, scores recovered to near MAXBROMO levels by POST2. 3. Bromocriptine was not associated with improvements in mood state.

Discussion

McDowell et al. (1998) found that bromocriptine may generally enhance performance on tasks through executive processes (e.g., the dual task, the trail making test, the Stroop Test, verbal fluency, and the Wisconsin Card Sorting Test). However, the authors did not find significant improvements based on the baseline condition of several executive measures (e.g., dual task, Stroop Test) or control task. Results of this study suggested that bromocriptine may have a selective effect on cognitive processes associated with executive control (McDowell et al., 1998). Powell et al. (1996) also found significant effects on measures of executive function, including the digit span, and verbal fluency. It should be noted that more recent literature suggested that routine use of bromocriptine in individuals with stroke or TBI is not recommended, but there are benefits for individuals presenting with minimally conscious state and vegetative state post-TBI (Kakehi & Tompkins, 2021). Newer studies are required to fully determine the potential of bromocriptine as a treatment for executive cognitive functions.

Conclusions

There is level 2 evidence that bromocriptine may improve executive function in individuals with TBI (McDowell et al., 1998; J. H. Powell et al., 1996).

KEY POINT

- Bromocriptine may improve executive function in individuals with TBI. However, additional studies are needed to fully determine the effectiveness of this treatment.

Growth Hormone Replacement Therapy

Following an ABI, it is not uncommon for individuals to be diagnosed with hypopituitarism. TBI is a risk factor for hypopituitarism, often developing in individuals across the brain injury spectrum and affecting cognitive performance (Pavlovic, Pekic, Stojanovic, & Popovic, 2019). Growth hormone replacement therapy (rhGH) is a well-tolerated treatment to reverse the effects of this condition and it has been used to improve function, quality of life and well-being in individuals presenting with GH deficiency post-TBI (Dubiel et al., 2018).

TABLE 22 | The Effect of Growth Hormone Replacement Therapy on Executive Function Post TBI.

Author Year Country Study Design Sample Size	Methods	Outcome
High et al. (2010) USA	**Population:** TBI. *Placebo* (n=11): Mean Age=39.1 yr; Time Post Injury=5.1 yr.	1. Overall study results did not show great improvements on the majority of assessments between groups.

Author Year Country Study Design Sample Size	Methods	Outcome
PEDro=8 N=23	*Active rhGH* (n=12): Mean Age=36.1 yr; Time Post Injury=11 yr. **Intervention:** Participants were randomized to either a growth hormone replacement injection (rhGH) group or a placebo injection. Initially the drug was administered at 200 *ug*, followed by a 200 *ug* increase every month until the dosage reached 600 *ug*. Both groups received these injections for one year. **Outcome Measure:** Wechsler Adult Intelligence Scale-III, Delis-Kaplan Executive Function System.	2. There was a significant improvement on the Finger tapping demonstrated in the treatment group. 3. Processing Speed Index: the treatment group improved significantly over the one-year period ($p<0.050$). The control group showed improvement at the end of the first 6 mo ($p<0.010$), but this was not seen at the end of the 1 yr. 4. Significant improvement was also noted on the Wisconsin Card Sorting Test (executive functioning) for the treatment group ($p<0.010$). 5. On the California Verbal learning Test-II improvement was noted for the treatment group on learning and memory.
Moreau et al. (2013) France PCT N=50	**Population**: TBI. Treatment Group (TG, n=23): Mean Age=37.9 yr; Gender: Male=19, Female=4; Mean Time Post Injury=7.8 yr; Mean GCS=8.1. Control Group (CG, n=27): Mean Age=37.1 yr; Gender: Male=24, Female=3; Mean Time Post Injury=5.5 yr; Mean GCS=9.4. **Intervention**: Participants were allocated to receive GH therapy (TG, 0.2-0.6mg/d) or no treatment (CG) for 1yr. Outcomes were assessed before (T1) and after (T2) treatment. **Outcome Measures**: Activities of Daily Living (ADL); Quality of Life Brain Injury (QOLBI); Verbal Memory (VM); Rey Complex Figure (RCF); Reaction Time (RT).	1. Both groups showed significant improvement in instrumental ADL (iADL, $p=0.001$) at T2, but not personal ADL (pADL). 2. Both groups showed significant improvement in QOLBI total scores ($p=0.019$) and intellectual ($p=0.001$), functional ($p=0.023$), and personal ($p=0.044$) subscores at T2, but not physical, psychological, and social subscores. 3. Both groups showed significant improvement ($p<0.050$) in aspects of attention (RT), memory (VM), and visuospatial (RCF) abilities at T2. 4. The TG showed significantly greater improvement in QOLBI functional ($p=0.023$) and personal ($p=0.019$) subscores, as well as RCF ($p=0.037$), but no significant difference was found for other outcome measures. 5. There was a significant correlation ($p<0.050$) between QOLBI total and pADL ($r=0.49$). 6. There was a significant negative correlation ($p<0.01$) between attention (RT) and pADL ($r=-0.59$) and iADL ($r=-0.56$).

Discussion

High et al. (2010) compared the long term (6 months and 1 year) effects of rhGH administration to placebo in a TBI population. Significant improvements were noted in executive functioning (Wisconsin Card Sorting Test) for both he rhGH and placebo groups. Comparing similar groups (rhGH to placebo), Moreau et al. (2013) found that patient quality of life, instrumental activities of daily living, attention, memory, and visuospatial ability improved over the treatment period in both the treatment and

control group. However, improvements in executive function, as measure by the digit span, were not observed (Moreau et al., 2013). Literature on the benefits of rhGH on individuals with TBI is considered scarce and fragmented, and more studies are needed to further characterize growth hormone deficits and the effect of rhGH in this population (Gasco, Cambria, Bioletto, Ghigo, & Grottoli, 2021).

Conclusions

There is conflicting (level 1b and level 2) evidence regarding the effectiveness of rhGH in improving executive functioning post TBI (High et al., 2010; Moreau et al., 2013).

KEY POINT

- The effectiveness of rhGH in improving executive functioning in individuals with TBI is unclear. More studies are needed to determine the benefits of this treatment for executive function.

Rivastigmine

Rivastigmine acts as an acetylcholinesterase inhibitor which prevents the enzyme acetylcholinesterase from breaking down acetylcholine (Liepert, 2016). This increases the concentration of acetylcholine in synapses. Acetylcholine has been most strongly linked with the hippocampus and memory deficits. Similar to donepezil, rivastigmine has been used to treat dementia in Alzheimer's disease and to facilitate cognitive recovery in individuals with TBI (Kakehi & Tompkins, 2021).

TABLE 23| The Effect of Rivastigmine on Executive Function Post ABI.

Author Year Country Study Design Sample Size	Methods	Outcome
Silver et al. (2006) USA RCT PEDro=9 N=123	**Population:** TBI. *Rivastigmine* (n=80): Mean Age=37 yr; Gender: Male=53, Female=27. *Placebo* (n=77): Mean Age=37.1 yr; Gender: Male=53, Female=24. **Intervention:** Participants were randomized to receive either rivastigmine (3-6 mg/d) or placebo. At the end of the first 4 wk, rivastigmine doses were increased to 3.0 mg, 2x/d. If necessary, doses were decreased to 1.5 mg or 4.5 mg 2x/d. **Outcome Measure:** Trails A and B, Hopkins verbal learning test (HVLT), Cambridge Neuropsychological Test Automated Batter Rapid Visual Information Processing (CANTAB RVIP A).	1. Results of the CANTAB RVIP A' and HVLT found no significant differences between the placebo group and the treatment group. 2. Rivastigmine was found to be well tolerated and safe.

Author Year Country Study Design Sample Size	Methods	Outcome
Silver et al. (2009) USA RCT PEDro=9 N=127	**Population:** TBI. *Ex-Rivastigmine* (n=65): Mean Age=36.9 yr; Gender: Male=43, Female=22; Time Post Injury=73.5 mo. *Ex-placebo* (n=62): Mean Age=38 yr; Gender: Male=42, Female=20; Time Post Injury=100.1 mo. **Intervention:** Participants were randomized to receive rivastigmine injections (1.5 mg 2x/d to a max of 12 mg/d) or placebo injection. **Outcome Measure:** Trails A and B, Hopkins verbal learning test (HVLT), Cambridge Neuropsychological Test Automated Batter Rapid Visual Information Processing (CANTAB RVIP A).	1. The mean final dose of rivastigmine was 7.9 mg/day. 2. Forty percent of participants were responders on CANTAB RVIP A' or HVLT score at week 38. 3. At the end of the study period all (n=98) were seen to improve of the CANTAB RVIP A' ($p<0.001$), the HVLT ($P<0.001$), and the Trails A and B ($p<0.001$). 4. Sub-analysis controlling for order effects revealed there were no significant differences between groups.

Discussion

In two studies rivastigmine was administered to patients who had sustained a moderate to severe TBI (Silver et al., 2006; Silver et al., 2009). Neither RCT found significant effects of rivastigmine on measures of general or executive function. Given the availability of alternative treatments, the use of rivastigmine has been generally avoided due to lack of meaningful benefits as reported by RCTs and inconclusive evidence on the use of this medication post TBI (Kakehi & Tompkins, 2021).

Conclusions

There is level 1b evidence that rivastigmine is not effective for improving executive functioning, compared to placebo, following an ABI (Silver et al., 2006; Silver et al., 2009).

KEY POINT

- Rivastigmine is not effective in remediating executive dysfunction post ABI.

Hyperbaric Oxygen Therapy

Hyperbaric oxygen therapy involves the inhalation of pure oxygen under pressure allowing the lungs to absorb more oxygen per breath. Currently hyperbaric oxygen therapy is used to treat decompression sickness, serious infections, and delayed wound healing as a result of a comorbid illness such as diabetes (The Mayo Clinic, 2019). Hyperbaric oxygen therapy has been used to treat cell death associated with TBI and stroke, and to alleviate memory loss, language difficulties and comprehension deficits in individuals with neurodegenerative diseases (Gonzalez-Portillo, Lippert, Nguyen, Lee, & Borlongan, 2019).

TABLE 24| The Effect of Hyperbaric Oxygen Therapy on Executive Functioning Post ABI

Author Year Country Study Design Sample Size	Methods	Outcome
Hadanny et al. (2018) Israel Case Series N=154	**Population:** Mean age=42.7yr; Gender: Male=58.4%, Female=43.6%; Mean time post-injury=4.6yr; Injury severity: mild=44.8%, moderate=15.6%, severe=39.6%. **Intervention:** All individuals received hyperbaric oxygen therapy (HBOT). Sessions consisted of 60-90 mins of 100% oxygen at 1.5/2 ATA exposure 5 days a week. **Outcomes:** NeuroTrax software subsets: general, memory, executive functions, attention, information processing speed, visual spatial processing, motor skills.	1. On measures of general cognitive functioning there was a significant increase in scores after HBOT treatment ($p<0.0001$). 2. Memory scores significantly increased following HBOT treatment ($p<0.0001$). 3. Executive function scores significantly increased following HBOT treatment ($p<0.0001$). 4. Attentional scores significantly improved following HBOT treatment ($p<0.0001$). 5. Information processes speed significantly increased following HBOT treatment ($p<0.0001$). 6. Visual spatial processing significantly improved following HBOT treatment ($p=0.005$). 7. Motor skills significantly improved following HBOT treatment ($p<0.0001$).

Discussion

In a case series study, Hadanny et al. (2018) evaluated the potential benefits of hyperbaric oxygen therapy on chronic neurocognitive deficits in individuals with ABI. This study used NeuroTrax to evaluate all neurocognitive measures. Both measures of general and executive functioning showed a significant improvement over the treatment period. However, it should be noted that this study did not have a control group; therefore, it may be difficult to separate the effects of the treatment from spontaneous recovery (Hadanny et al., 2018).

Conclusions

There is level 4 evidence that hyperbaric oxygen therapy may improve executive function following an ABI (Hadanny et al., 2018).

KEY POINT

- Hyperbaric oxygen therapy may be beneficial for improving executive function following an ABI; however, more research is needed.

Rehabilitation of General Cognitive Functioning

Non-Pharmacological Interventions

Interventions for the treatment of cognitive deficits post TBI tend to be diverse with variability between the interventions themselves and the outcome measures used to document results. Gordon et al. (2006) conducted an extensive review of the TBI rehabilitation literature and identified 13 studies examining treatments for cognitive deficits. Cognitive rehabilitation has been provided through a comprehensive holistic approach that addresses cognitive deficits and uses interventions that aim to improve individuals' emotional, motivational and interpersonal functioning (Gordon et al., 2006).

Several researchers have noted that training-based therapies that target executive control, such as "*attention, problem solving, and the use of metacognitive strategies*" (Novakovic-Agopian et al., 2011) may improve functioning in those who sustain an ABI (Cicerone, 2002; Kennedy et al., 2008; Sohlberg et al., 2003b). Studies included in this section have examined the effects of cognitive rehabilitation strategies on general cognitive functioning.

General Cognitive Rehabilitation Programs

TABLE 25 | The Effect of General Cognitive Rehabilitation Programs on General Cognitive Function Post ABI

Author, Year Country Study Design Sample Size	Methods	Outcome
Linton & Kim (2018) United States RCT PEDro=5 N=8	**Population:** Mean age=36.5yr; Gender: Male=4, Female=4. **Intervention:** Participants were either assigned to the 3-month, in home, *Trabajadora de Salud* group or the control group. The control group received the same intervention only via telephone. **Outcomes:** Neurobehavioral Functioning Inventory, Physical FIM, Cognitive FIM.	1. Both the experimental and control groups saw a decrease in their depressive symptoms on the Neurobehavioral Functioning Inventory. 2. Both groups saw an increase in physical FIM scores, although the experimental groups scored slightly higher. 3. Only the experimental group saw an increase in Cognitive FIM scores. 4. No between-subjects' analyses were performed.
Schmidt et al. (2013) Australia RCT PEDro=8 N=54	**Population:** *Video Feedback (N=18)*: Mean age=42.7yr; Gender: Male=14, Female=4; Mean time post-injury=1.5yr; Mean GCS=8.1. *Verbal Feedback (N=18):* Mean age=41.6yr; Gender: Male=14, Female=4; Mean time post-injury=4.7yr; Mean GCS=7.1. *Experimental Feedback (N=18):* Mean age=37.5yr; Gender: Male=18; Mean time post-injury=5.8yr; Mean GCS=7.0.	1. There were significant differences between groups at baseline on measures of functional independence ($p<0.01$), and logical memory ($p<0.05$). 2. The video feedback group significantly improved online awareness more than either of the other two groups ($p<0.001$) and had significantly fewer errors than either group ($p<0.05$).

	Intervention: Participants received instructions for meal preparation on 4 occasions in one of three formats. The video feedback group watched their recorded meal preparation sessions, the verbal feedback group received feedback on task completion without the video, and the experimental group received no therapist feedback on task completion. **Outcomes:** Error rate, Awareness Questionnaire (AQ), Depression Anxiety Stress Scales (DASS-21), Self-perceptions in Rehabilitation Questionnaire (SPIRQ).	3. The video feedback group had significantly higher intellectual awareness on the AQ ($p<0.05$). 4. There were no significant differences between groups on the DASS-21 or the SPIRQ.
Goverover et al. (2007) United States RCT PEDro=6 N=20	**Population:** *Experimental Group (N=10)*: Mean age=39.5yr; Gender: Male=8, Female=2; Mean time post-injury=12.9mo; Mean GCS=4.6. *Control Group (N=10)*: Mean age=39.2yr; Gender: Male=8, Female=2; Mean time post-injury=8.6mo; Mean GCS=3.6. **Intervention:** Six individualized cognitive treatment task sessions were administered over three weeks, with one session per day 2-3 days a week. Tasks included everyday activities such as making lunch, or a telephone call. **Outcomes:** Assessment of awareness of disability (AAD), Assessment of Motor and Process Skills (AMPS), Activities of Daily Living (ADL), Relf-Regulation Skills Interview (SRSI), Satisfaction with quality of care, Awareness Questionnaire (AQ), Community Integration Questionnaire (CIQ).	1. Groups were not statistically different at baseline. 2. There were no significant differences between groups following treatment on AAD. 3. There was a significant improvement in the experimental group on SRSI scores compared to the control group ($p<0.05$). 4. There was a significant improvement in AMPS and ADLs for the experimental group, compared to the control group ($p<0.05$, $p<0.05$), only on measures of processing and cognition. There were no significant differences on measures of motor AMPS or motor ADLs. There were no significant differences between groups on AQ or CIQ.
Neistadt et al. (1992) USA RCT PEDro=6 N=45	**Population:** TBI: Mean Age=33.2 yr; Gender=Male; Time since injury=7.9 yr. **Intervention:** Participants were randomly assigned to an adaptive (n=23) or a remedial (n=22) approach for their occupational therapy. **Outcome Measure:** The Parquetry Block test; Block design subtest of the Wechsler Adult Intelligence Scale-Revised (WAIS-R).	1. After treatment, the remedial group improved significantly more than the adaptive group on the Parquetry Block test ($p=0.019$), but there were no significant differences on the WAIS-R Block Design subtest. 2. There was a non-significant tendency in the expected direction to support that the adaptive group would perform better than the remedial group on the RKE-R after treatment.
Beaulieu et al. (2021) USA Pre-Post N=1760	**Population*:*** TBI***;*** Severity: Mild=246, Moderate-Severe=669, Not Reported=845; Mean Age=44.41yr; Mean Time Post Injury<1yr. **Intervention:** Participants received quasi-contextualized speech therapy (ST) in acute inpatient rehabilitation at one of 9 US sites. Quasi-contextualized therapy included learning compensatory or metacognitive strategies, daily problem solving, and verbalization of hypothetical daily scenarios. Three hours of physical therapy, occupational therapy, and speech therapy were delivered for approximately 30min per day. Outcome measures were assessed at discharge, 3- and 9-months post discharge.	1. Participants showed significantly better scores on the PART-O Total and FIM adjusted scores at discharge, and at 3 and 9mo ($p<.05$). 2. Those who received a greater proportion of contextualized treatment following ST demonstrated higher PART-O Total scores at both 3- and 9-mo post discharge ($p<.05$). 3. No significant impact was noted for FIM, PART-O Productivity, or PART-O social at 3 months, SWLS, or depression at any time point. 4. Quasi-contextualized therapy was associated with better community participation and motor and cognitive function during the year following discharge ($p<.05$).

	Outcome Measures: Satisfaction with Life Scale (SWLS), Patient Health Questionnaire-9 (PHQ-9), Participation Assessment with Recombined Tools-Objective-17 (PART-O-17), Functional Independence Measure (FIM)-Motor and Cognitive Sub scores.	
Bertoni et al. (2020) Italy Case Series $N_{Initial}$=94 N_{Final}=87	**Population***:* TBI=38, Vascular Etiology=41, Anoxia=15; Mean Age=32.33yr; Gender: Male=69, Female=25; Mean Time Post Injury=77days. **Intervention:** Participants were subdivided into two groups based on the Level of Cognitive Functioning scale (LCF) at admission. Participants with an LCF≥6 were assigned to Group 1, in which participants underwent formal neuropsychological (NPS) assessment and a personalized cognitive rehabilitation program. Participants with an LCF<6 were assigned to Group 2 only participated in basic tests since cognitive impairment did not allow access to formal NPS assessment. **Outcome Measures:** Cognitive Reverse Index questionnaire (CRIq), modified Barthel Index (mBI), Disability Rating Scale (DRS), Trail Making Test (TMT), Onset-Admission Interval (OAI).	1. The whole sample showed a significant improvement in motor performance measured with disability scales (mBI and DRS) between admission and discharge (p<0.001). 2. A significant correlation was found between OAI and CRIq (p=0.019). The earlier the rehabilitation starts, the greater the gain in part B of TMT (p=0.013). 3. There was a significant gain in DRS score in the vascular etiology and TBI group (p<0.001), whereas the gain was not significant in the anoxia group (p=0.500). 4. Assessments following rehabilitation showed a significant gain in the DRS for participants with a higher cognitive reserve (CRIq≥85). 5. A significant negative correlation was found between CRIq scores and time to achieve criteria for access to neuropsychological assessment.
Rasquin et al. (2010) Netherlands Cohort N=52	**Population:** Mean Age: 49.5 yr; Gender: male=14, female=13; Mean Time Post-Injury:1.9 yr; Condition: CVA=9, TBI=5, Other ABI=13. Controls who were relatives of the patients=25. **Intervention:** Participants were asked to formulate individual strategies to address specific cognitive issues (attention memory or problem solving) and to develop methods to ask for help with problems resulting from the head injury. Caregivers were asked to attend sessions. Sessions lasted approximately 2.5 hours and ran for approximately 15 weeks. Assessment was conducted at baseline, 21 weeks after treatment, 6 months after treatment. **Outcome Measure:** Goal Attainment Scaling; Stroke Adapted Impact Scale; Cognitive Failure Questionnaire	1. Results from the Goal Attainment Scaling, the Stroke Adapted Impact Scale and the Cognitive Failure Questionnaire all indicate there was significant improvement from baseline (T0) to immediately after treatment (T1) (p<0.05). 2. Participants improved on significantly on individual goals (p<0.05) between T0 to T1. 3. No further changes were noted on the primary outcomes 6 months post intervention (T2).
Laatsch et al. (1999) USA Case series N=5	**Population:** TBI; Age Range=18-65yr; Time Post-Injury=2-48 months. **Intervention:** Cognitive rehabilitation therapy (CRT) programme in a longitudinal protocol involving a resting SPECT and neuropsychological evaluation at pre-treatment, post-treatment, and post non-treatment intervals. **Outcome Measure:** Neuropsychological	1. SPECT data revealed significant increases in cerebral blood flow during the treatment period (p<0.05). 2. CRT was found to be effective in improving both NP and everyday functioning. All participants were able to be more productive in their lives following treatment. 3. All five cases presented here demonstrated improvements in neuropsychological abilities.

	measures: WAIS-R, WMS-R, CVLT, RCFT, SCWT, WCST or ACT, SPECT image.	
Freeman et al. (1992) United States PCT N=12	**Population:** TBI; *Experimental Group (N=6):* Mean age=38.5yr; Mean time post-injury=33.33mo. *Control Group (N=6)*: Mean age=47.83yr; Mean time post-injury=11.83mo. **Intervention:** The intervention consisted of being enrolled in a 6mo cognitive rehabilitation programme which met 3d/wk, for 2hr. The control group received no such treatment. **Outcome Measures:** Wechsler Adult Intelligence Scale for Children (WAIS-R)	1. Post-intervention the experimental group was seen to have significantly improved scores on the WAIS-R compared to the control group (p=.02).

Discussion

Linton et al. (2018) examined the effect of an in-home program (*Trabajadora de Salud*) on functional abilities, hospital readmission, rehabilitation, symptoms and depression, as well as on employment and caregiver burden among Latin American individuals with TBI and their caregivers. The authors found that although both experimental and groups improved on physical measures over time, only the experimental group saw a significant increase in cognitive FIM scores.

A study by Schmidt et al. (2013), involved individuals receiving task completion instructions in a variety of formats to determine how feedback might influence general cognition. Participants in the video feedback group (compared to verbal feedback) saw significant improvements in self-perception, and general awareness. The video feedback condition showed a recording of the individual performing the meal preparation task required with corrective feedback, compared to the verbal feedback group which only received verbal corrective feedback (Schmidt et al., 2013).

In a pre- post study, Beaulieu et al. (2021) examined the effects of a quasi-contextualized speech therapy applied to cognitive and language deficits to improve performance on functional outcomes and everyday activities in individuals with TBI. The authors found that participants reported better community participation in the year after discharge; additionally, quasi-contextualized treatment was associated with better cognition function at the point of discharge and in the year after discharge (Beaulieu et al., 2021).

Neistadt (1992) divided 45 participants into one of two groups: a remedial group who received individual training with parquetry block assembly, and an adaptive group who received functional skills training over a six-week period. Outcomes for the effect of treatment for constructional test performance revealed that the remedial group improved significantly more than the adaptive group on the Parquetry Block test. However, there were no significant differences on the WAIS-R Block Design subtest after treatment. Training-specific learning appears to be an effective approach to rehabilitation as demonstrated by the treatment effect. The effectiveness of remediation treatment was also examined by Freeman et al. (1992). The authors compared the effectiveness of a memory remediation treatment,

consisting of executive and compensatory memory retraining, with no treatment. The authors found that the treatment group exhibited significant improvements, indicating that the program may be effective for individuals with TBI (Freeman et al., 1992).

Goverover et al. (2007) conducted an RCT to study individualized cognitive treatments (such as making lunch or a telephone call) on the ability to remediate self-awareness and generalized processing skills. Groups did not significantly differ at baseline; however, following treatment individuals in the treatment group experienced a significant increase in their self-regulation, and processing skills (Goverover et al., 2007).

In a cohort study, Rasquin and colleagues (2010) they investigated the effectiveness of a low intensity outpatient cognitive rehabilitation program on individuals (n=27) who had sustained an ABI. All participants were in the chronic phase of recovery, and all were asked to invite a caregiver to attend sessions with them (n=25). Participants worked on developing strategies to assist them with their attention, memory, and problem-solving difficulties. Social skills training sessions were also held. Changes were noted immediately after the cognitive rehabilitation program ended and this improvement in goal attainment, and cognitive improvement was maintained at the 6-month follow-up. Laatsch et al. (1999) found similar results in a study where cognitive rehabilitation therapy helped individuals increase productivity in their daily lives and found improvements on neuropsychological measures. The effects of intensive rehabilitation on cognitive reserve were studied by Bertoni et al. (2020). The authors found that individuals with severe TBI who received intensive rehabilitation showed significant improvements in overall disability status and cognition.

Conclusions

There is level 1b evidence that corrective video feedback is more effective for improving generalized cognitive functioning and self awareness compared to verbal feedback only in individuals with an ABI (Schmidt et al., 2013).

There is level 1b evidence that cognitive therapies compared to standard therapy are more effective than no therapy for improving generalized cognitive functioning, as well as self-awareness following an ABI (Goverover et al., 2007).

There is level 1b evidence that remedial occupational therapy and adaptive occupational therapy may have equal effects on generalized cognitive function in those with an ABI (Neistadt, 1992).

There is level 2 evidence that an in-home program, Trabajadora de Salud, may improve general cognitive functioning compared to standard therapy for individuals with an ABI, particularly individuals from Latin America (Linton & Kim, 2018).

There is level 2 evidence that executive and compensatory memory retraining may be effective for general cognition in individuals with TBI (Freeman et al., 1992).

There is level 4 evidence that a low intensity outpatient cognitive rehabilitation program may improve goal attainment and cognitive impairment in individuals post ABI (Rasquin et al., 2010).

There is level 4 evidence that the use of quasi-contextualized treatment may improve cognitive outcomes in individuals with TBI (Beaulieu et al., 2021).

There is level 4 evidence that an intensive rehabilitation program may enhance cognitive reserve in individuals with severe TBI (D. Bertoni et al., 2020).

KEY POINTS

- General cognitive rehabilitation programs are effective for improving cognitive functioning following an ABI.
- Corrective video feedback is more effective than verbal feedback alone for improving general cognitive function and self-awareness.
- Remedial and adaptive occupational therapy are equally effective for improving general cognitive functioning.
- An in-home program, Trabajadora de Salud, may improve general cognitive functioning compared to standard therapy for Latin American individuals with an ABI.
- Quasi-contextualized treatment may enhance cognitive outcomes for individuals with TBI.

Drill & Practice Training

The following study examines the influence of "drill & practice" exercises. Drill and practice training targets attention and general cognitive skills through repetitive training of specific tasks.

TABLE 26 | The Effect of Drill & Practice Training on General Cognitive Function Post ABI

Author, Year Country Study Design Sample Size	Methods	Outcome
Afsar et al. (2021) India Pre-Post N=12	**Population***:* TBI; Moderate-Severe=12; Mean Age=32.33yr; Gender: Male=9, Female=3; Mean Time Post Injury=11.37mo. **Intervention:** Participants underwent a hospital-based cognitive retraining (CR) intervention for three days per week for two months. The CR intervention included five tasks and aimed at enhancement of impaired cognitive functions through repetitive practice and drills. Outcome assessments were	1. Participants exhibited significant changes at post intervention in the domains of processing speed (DSST), working memory (Spatial Span), executive function and planning (Tower of London), visuo-spatial construction (CFT-Copy), visual memory (CFT-Delayed Recall), and verbal memory (AVLT-Total Learning). 2. AVLT-Total Learning scores represented the individual's capacity to learn information over trials and is considered as the measures of

	measured at baseline and post-intervention. **Outcome Measures:** Visual Analogue Scale (VAS), Perceived Stress Scale (PSS), Rivermead Post-Concussion Symptoms Scale (RPCSS), World Health Organization Quality of Life Scale-Brief (WHOQLS-Brief), Digit Symbol Substitution Test (DSST), Complex Figure Test-Copy (CFT-Copy), Complex Figure Test-Delayed Recall (CFT-Delayed Recall), Rey's Auditory Verbal Learning Test-Total Learning (AVLT-Total Learning).	memory encoding, whereas Recall trials are considered as the measures of memory retention. 3. At post-intervention, participants exhibited significantly lower amounts of perceived stress (PSS), lower levels of post-concussive symptoms (RPCSS), and higher levels of psychological quality of life (WHOQLS-Brief).

Discussion

In a pre-post trial, Afsar et al. (2021) found that a hospital-based cognitive retraining program focused on repetitive practice and drills was able to help individuals with TBI improve their processing speed and working memory. Executive function and planning, assessed by the Tower of London test also showed improvements.

Conclusions

There is level 4 evidence that a cognitive retraining program may improve processing speed, working memory and executive function following moderate to severe TBI (Asfar et al. 2021).

KEY POINTS

- **Cognitive retraining program focused on repetitive practice and drills may improve processing speed, working memory and executive function following moderate to severe TBI.**

Yoga

A holistic approach to rehabilitation can be beneficial for individuals who have sustained a TBI. Yoga relates to the integration of body, mind and spirit, and it can be used as a therapy aid for individuals with chronic TBI, as it involves relaxation of the body, posture, breathing and meditation (Schmid, Miller, Van Puymbroeck, & Schalk, 2016). Previous literature has examined the feasibility of yoga as a therapeutic activity for individuals with ABI that may enhance mobility, balance and self-reported occupational performance (Stephens, van Puymbroeck, Sample, & Schmid, 2020).

TABLE 28 | The Effect of Yoga on General Cognitive Function Post TBI

Author, Year Country Study Design Sample Size	Methods	Outcome

Donnelly et al. (2021) USA Pre-Post N=857	**Population***: TBI (n=705);* Severity: Mild=326, Moderate=181, Severe=197, Not Reported=1; Mean Age=43yr; Gender: Male=173, Female=530, Not Reported=2; Mean Time Post Injury=4.8yr. *Caregivers (n=152):* Mean Age=49yr; Gender: Male=23, Female=129. **Intervention:** Participants with a TBI and caregivers received a LoveYourBrain yoga program with psychoeducation, involving didactic material, question prompts, and skill-building exercises in resilience and community connection. The program was offered for 90 min once per week for six weeks. **Outcome Measures:** Neurology Quality-of-Life (Neuro-QOL), Quality of Life After Brain Injury-overall scale (QOLIBRI-OS), Resilience, Cognition, Positive Affect and Well-being, Traumatic Brain Injury Quality of Life (TBI-QOL).	1. The satisfaction with the program was rated 9.3 out of 10, which was similar in both groups (9.3 for people with TBI and 9.4 for caregivers). 2. Univariate analyses revealed that the participants with TBI experienced significant improvements in their scores on the QOLIBRI-OS ($p<0.0000$), Resilience ($p<0.0004$), Cognition ($p<0.0000$), and Positive Affect and Well-being measures ($p<0.0000$) from baseline to post-intervention. 3. For QOLIBRI-OS, there was a significant interaction between people 55 and 70 years of age and time ($p=0.007$), suggesting that the positive impact of the program on quality of life may be less for older people compared to younger people. 4. There was a significant interaction between gender and time ($p=0.047$) for well-being, suggesting that the program may have had a slightly more positive affect on women as compared to men.

Discussion

One pre-post study by Donnelly et al. (2021) involved yoga sessions for individuals living with a TBI and their caregivers that included 10 minutes of breathing exercises, 45 minutes of gentle yoga, and 15 minutes of guided meditation. Yoga sessions aimed to improve attention control, emotional regulation, and self-efficacy. Participants reported high levels of satisfaction with the program and a significant improvement in quality of life, positive affect and wellbeing, and cognitive measures were observed. The authors also found that the positive impact of yoga can be more significant for younger people than for older people. Qualitative data showed that some of the components of the program (e.g., mindfulness, self-compassion) were perceived by the participants as helpful tools to overcome challenges related to their injury and to navigate overwhelming environments. According to a systematic review most of the studies that examine the effectiveness of yoga for individuals living with brain injury focus specifically on stroke populations, are low quality and did not report on comparisons between groups (PEDro scale <5) (Silveira & Smart, 2019).

Conclusions

There is level 4 evidence that a yoga intervention may enhance general cognitive functioning in individuals with TBI (Donnelly et al., 2021).

KEY POINTS

- Yoga may be an effective therapy to improve cognition in individuals with TBI.

Technological Interventions

Computer-based Interventions

In recent years, a surge in computer technology has allowed for the development of computer-based interventions. Generally, cognitive-based computer programs have demonstrated to be effective on measures of cognitive functioning (Johansson & Tornmalm, 2012). Computerized cognitive training is a low cost, user-friendly and accessible intervention that may improve cognition in individuals with ABI; additionally, computer interventions can be relatively easy implemented in a clinical setting or a in a home environment (Sigmundsdottir et al., 2016).

TABLE 29 | The Effect of Computer-based Interventions on General Cognitive Function Post ABI

Author, Year Country Study Design Sample Size	Methods	Outcome
Li et al. (2015) USA Pre-Post $N_{Initial}$=13 N_{Final}=12	**Population:** Stroke=5, TBI=5, Brain tumor=2; Mean Age=61 yr; Gender: Male=10, Female=2. **Treatment:** Participants received the computer-based cognitive retraining program, Parrot Software. The following eight modules were each completed in separate 1 h sessions: Visual Instructions, Attention Perception and Discrimination, Concentration, and Visual Attention Training, Remembering Written Directions, Remembering Visual Patterns, Remembering Written Letters, and Remembering Written Numbers. **Outcome Measure:** Montreal Cognitive Assessment (MoCA overall, attention, memory), Medication-box sorting task.	1. Compared to baseline, there was a significant mean increase in overall MoCA of 3.25 (p=0.030) post-intervention. However, the attention and memory subscales did not show significant differences. 2. There were no significant differences before and after intervention for the medication-box sorting task. 3. Participants with previous computer-based cognitive retraining experience had significantly more MoCA improvement than those without (p<0.010). 4. Age, education level, or type of ABI diagnosis did not have any significant effects on MoCA or medication-box scores.

Discussion

Li et al. (2015) examined the effectiveness of the Parrot Software program, a computer-based cognitive retraining program, on global cognition, as well as attention and memory skills in individuals with ABI. Cognitive outcomes were assessed using the MoCA and the medication-box sorting task. The authors found significant statistical differences in baseline and post-test global cognition scores after the

cognitive retraining intervention, indicating that the intervention using the Parrot software may be effective to improve global cognition post ABI (Li et al., 2015).

Conclusion

There is level 4 evidence that the Parrot computer-based cognitive retraining program may enhance general cognitive functioning in individuals with ABI (Li et al., 2015).

KEY POINTS

- The Parrot computer-based cognitive retraining program may improve general cognition post ABI.

Mindfulness

TABLE 30 | The Effect of Mindfulness Interventions on General Cognitive Function Post ABI

Author, Year Country Study Design Sample Size	Methods	Outcome
Combs et al. (2018) United States Pre-Post N=19	**Population:** Mean age=32.8yr; Gender: Male=89.5%, Female=10.5%; TBI injury severity: mild=15.8%, severe=63.2%, Other=21.1%. **Intervention:** All individuals experienced weekly group meetings around topics in mindfulness-based stress reduction. Each group session lasted 60 mins and group sessions were completed over the course of 32 weeks. **Outcomes:** Participants were asked dichotomous questions, or on a Likert-scale about their psychological wellbeing, cognitive functioning, and physical health and their beliefs of the efficacy of the intervention related to those topics.	1. Overall, most participants reported a significant improvement in their overall health ($p<0.001$) in relation to the number of sessions they attended. 2. Participants also reported their beliefs in the ability of the number of sessions to improve physical health symptoms ($p<0.05$), focus and attention ($p<0.05$), self-awareness ($p<0.05$), and mood and anxiety ($p<0.001$). 4. No similar significant relationship was found for measures on sleep benefits, or pain.

Discussion

A Mindfulness-based stress reduction intervention was implemented to improve self-awareness and overall cognitive health (Combs et al., 2018). Individuals participated in weekly mindfulness sessions for 60 minutes and were asked to self-report on their general cognitive functioning. Individuals reported a significant reduction in cognitive deficits which was positively correlated to the number of sessions they attended. This was true for both general cognitive functioning as well psychological wellbeing. Although

this single pre-post study offers insight into the benefits of mindfulness-based stress reduction, more research is needed to determine the effectiveness of this intervention in improving general cognition in individuals with ABI.

Conclusions

There is level 4 evidence that mindfulness-based stress reduction intervention may be effective for improving general cognitive functioning in individuals with an ABI (Combs et al., 2018).

KEY POINTS

- A mindfulness-based stress reduction intervention may be effective for improving cognitive functioning. However, more research is needed.

Pharmacological Interventions

Methylphenidate

Methylphenidate is a central nervous stimulant that increases the synaptic and extracellular concentrations of dopamine (Barnett & Reid, 2020). This medication has been used to treat Attention Deficit Hyperactivity Disorder in adults and children (Cândido et al., 2021), as well as to treat mental fatigue and to help improve cognitive function in individuals with TBI (Johansson et al., 2017; Levin et al., 2019).

TABLE 31 | The Effect of Methylphenidate on General Cognitive Functioning Post TBI

Author, Year Country Study Design Sample Size	Methods	Outcome
Zhang and Wang (2017) China RCT PEDro=10 $N_{Initial}$=36, N_{Final}=33	**Population:** TBI; Severity: mild to moderate. *Methylphenidate Group (n=18)*: Mean Age=36.3 yr; Gender: Male=13, Female=5. *Placebo Group (n=18)*: Mean Age=34.9 yr; Gender: Male=14, Female=4. **Treatment:** Participants were randomly assigned to receive methylphenidate (flexibly titrated from 5 mg/d at the beginning, then gradually increased by 2.5 mg/d until reaching 20 mg/d) or placebo for 30 wk. **Outcome Measures:** Mental Fatigue Scale (MFS), Choice Reaction Time (CRT), Compensatory Tracking Task (CTT), Mental Arithmetic Test (MAT), Digit Symbol Substitution Test (DSST), Mini-Mental State Examination (MMSE), Beck Depression Inventory (BDI), Hamilton Rating Scale for Depression (HAMD).	1. At baseline, there were no significant differences between groups in terms of demographics, MFS, CRT, CTT, MAT, DSST, MMSE, BDI, or HAMD. 2. Post-intervention, the experimental group had significantly lower scores compared to control group for MFS ($p=0.005$), CRT ($p<0.001$), CTT ($p<0.001$), BDI ($p=0.040$), and HAMD ($p=0.005$). 3. Post-intervention, the experimental group had significantly higher scores compared to control group for MAT ($p=0.020$), DSST ($p<0.001$), MMSE ($p<0.001$).

Discussion

Conversely, Zhang and Wang (2017) used a larger sample size to investigate the effects of long-term (30 wk) methylphenidate use in individuals post TBI. There were no significant differences at baseline between groups. Methylphenidate showed effectiveness in reducing mental fatigue and depression scores. Significant differences were also found in cognitive function scores, as measured by the Mental Arithmetic Test, Choice Reaction Time, Compensatory Tracking Task, Digit Symbol Substitution Test, and the Mini-Mental State Examination.

Conclusions

There is level 1b evidence that methylphenidate may improve general cognition in individuals with TBI (Zhang & Wang, 2017).

KEY POINTS

- Methylphenidate may improve general cognition functioning in individuals with TBI.

Amantadine

Amantadine is an antagonist of N-methyl-D-aspartate receptors and an agonist of the dopaminergic system (Liepert, 2016), and it is also considered to work pre- and post-synaptically by increasing the amount of dopamine in the synapse (Napolitano et al., 2005). Amantadine has been used to treat dyskinesia in Parkinson's disease and to facilitate cognitive recovery in individuals with TBI (Loggini et al., 2020).

TABLE 32 | The Effect of Amantadine on Executive and General Cognitive Functioning Post ABI

Author Year Country Study Design Sample Size	Methods	Outcome
Ghalaenovi et al. (2018) Iran RCT PEDro=10 N=40	**Population:** *Amantadine Group (N=19)*: Mean age=32.16yr; Gender: Males=19, Female=0; Mean GCS=7.1; Mean time post-injury=3.21days. *Control Group (N=21)*: Mean age=40.95yr; Gender: Male=18, Female=3; Mean GCS=6.95; Mean time post-injury=3.42days. **Intervention:** Participants either received a placebo or 100mg of amantadine twice a day for 6 weeks. Assessments were conducted at baseline, day 3 of treatment, day 7 of treatment, at 6-weeks completion	1. There were no significant differences observed on the MMSE, GOS, DRS, or KPS. It should be noted that these measures were only taken at baseline and 6-month follow-up. 2. On day 7 the amantadine group had significantly better rising GCS scores than the control group (p=0.044). No other significant differences were observed between groups.

Author Year Country Study Design Sample Size	Methods	Outcome
	of the intervention, and 6 months post initial start time. **Outcomes:** Mini-Mental State exam (MMSE), Glasgow Outcome Scale (GOS), FOUR score, Disability Rating Scale (DRS), Karnofsky Performance Scale (KPS), mean hospitalization time.	

Discussion

Ghalaenovi et al. (2018) examined the effectiveness of amantadine in enhancing recovery post TBI, including the improvement of the individual's level of consciousness, memory, disability, general cognition, mortality, and performance. The authors did not find any significant effects on the reported measures, indicating that amantadine may not improve general cognition in individuals with TBI.

Conclusions

There is level 1b evidence that amantadine may not improve general cognition in individuals with TBI (Ghalaenovi et al., 2018).

KEY POINTS

- Amantadine may not improve general cognition functioning in individuals with TBI.

Growth Hormone Replacement Therapy

Following an ABI, it is not uncommon for individuals to be diagnosed with hypopituitarism. TBI is a risk factor for hypopituitarism, often developing in individuals across the brain injury spectrum and affecting cognitive performance (Pavlovic et al., 2019). Growth hormone replacement therapy (rhGH) is a well-tolerated treatment to reverse the effects of this condition and it has been used to improve function, quality of life and well-being in individuals presenting with GH deficiency post-TBI (Dubiel et al., 2018).

TABLE 33 | The Effect of Growth Hormone Replacement Therapy on General Cognitive Functioning Post ABI.

Author Year Country Study Design Sample Size	Methods	Outcome
Reimunde et al. (2011) Spain Cohort N=19	**Population:** TBI; Gender: Male=19, Female=0. With Growth Hormone Deficiency (GHD) Group (n=11): Mean Age=53.36 yr; Mean Time Post Injury=44.55 mo. Without GHD group (n=8): Mean Age=47.12 yr; Mean Time Post Injury=46.6 mo. **Intervention:** Those with GHD received recombinant human GH (rhGH), subcutaneously (0.5 mg/d for 20d then 1 mg/d for 5 d). Those without GHD were given a placebo. Cognitive rehabilitation was given to everyone (1 hr/d, 5d for 3 mo). **Outcome Measure**: Weschler Adult Intelligence Scale (WAIS).	1. Results of the WAIS indicated that the control group improved significantly on the digits and manipulative intelligence quotient ($p<0.050$). 2. For those in the treatment groups improvement was noted in cognitive parameters: understanding digits, numbers, and incomplete figures ($p<0.050$) and similarities vocabulary, verbal IQ, Manipulative IQ, and total IQ ($p<0.010$).

Discussion

Reimunde et al. (2011) examined the use of recombinant human growth hormone in a cohort study. Results indicated that those receiving the rhGH improved significantly on the various cognitive subtests such as: understanding, digits, numbers, and incomplete figures ($p<0.05$), verbal IQ, Manipulative IQ, and Total IQ ($p<0.01$). The control group also showed significant improvement but only in digits and manipulative intelligence quotient ($p<0.05$). Of note IGF-I levels were similar between both groups at the end of the study.

Conclusions

There is level 2 evidence that rhGH administration may improve general cognitive functioning in individuals with TBI (Reimunde et al., 2011).

KEY POINT

- Growth Hormone Replacement Therapy may enhance general cognitive functioning in individuals with TBI.

Dextroamphetamine

Dextroamphetamine is another central nervous stimulant, and like methylphenidate, it is commonly used to treat narcolepsy and attention deficit hyperactivity disorder (Cutler et al., 2022). Dextroamphetamine is a non-catecholamine and sympathomimetic amine that acts as a stimulant.

TABLE 34 | The Effect of Dextroamphetamine on General Cognitive Functioning Post ABI.

Author Year Country Study Design Sample Size	Methods	Outcome
Hart et al. (2018) United States RCT PEDro=10 N=32	**Population:** TBI; *DEX Group (N=17)*: Mean age=39.6yr; Gender: Male=11, Female=6; Mean GCS=8.2; Mean time post injury=53.6d. *Control Group (N=15):* Mean age=38.7yr; Gender: Male=15, Female=0; Mean GCS=7.5; Mean time post injury=60.2d. **Intervention:** Participants either received the placebo or 10 mg of dextroamphetamine (DEX). Each treatment was administered once per day for 3wk. **Outcomes:** Moss Attention Rating Scale, Hopkins Rehabilitation Engagement Rating Scale, Cognitive Failures Questionnaire (CFQ), Rating Scale of Attentional Behavior (RSAB), Finger Taping Test, the Symbol Digit Modalities Test, Disability Rating Scale, Agitated Behavior Scale (ABS), Profile of Mood States.	1. There was a significant difference between groups on the ABS (p=0.04), with the DEX group demonstrating more agitation over time. 2. No other significant between group differences were found.

Discussion

Based on a single study, it does not appear that dextroamphetamine has any beneficial effects on general cognitive functioning in individuals with ABI. Small effects were observed favoring dextroamphetamine over placebo on Rating Scale of Attentional Behaviour and Cognitive Failures Questionnaire (CFQ). Family ratings for the CFQ indicated worse overall cognition for the group taking dextroamphetamine. In addition, emotional distress and agitation were worse for the experimental group (Hart et al., 2018).

Conclusions

There is level 1b evidence that dextroamphetamine does not global cognitive functioning following an ABI (Hart et al., 2018).

KEY POINT

- Dextroamphetamine may not improve global cognitive functioning in individuals with ABI and may increase agitation and emotional distress.

References

Afsar, M., Shukla, D., Bhaskarapillai, B., & Rajeswaran, J. (2021). Cognitive Retraining in Traumatic Brain Injury: Experience from Tertiary Care Center in Southern India. *Journal of neurosciences in rural practice, 12*(2), 295-301. doi:https://dx.doi.org/10.1055/s-0041-1722817

Al-Adawi, S., Al-Naamani, A., Jaju, S., Al-Farsi, Y. M., Dorvlo, A. S. S., Al-Maashani, A., . . . Qoronfleh, M. W. (2020). Methylphenidate improves executive functions in patients with traumatic brain injuries: a feasibility trial via the idiographic approach. *BMC Neurol, 20*(1), 103. doi:10.1186/s12883-020-01663-x

Alashram, A. R., Annino, G., Padua, E., Romagnoli, C., & Mercuri, N. B. (2019). Cognitive rehabilitation post traumatic brain injury: A systematic review for emerging use of virtual reality technology. *J Clin Neurosci, 66*, 209-219. doi:10.1016/j.jocn.2019.04.026

Banos, J. H., Novack, T. A., Brunner, R., Renfroe, S., Lin, H. Y., & Meythaler, J. (2010). Impact of early administration of sertraline on cognitive and behavioral recovery in the first year after moderate to severe traumatic brain injury. *J Head Trauma Rehabil, 25*(5), 357-361. doi:10.1097/HTR.0b013e3181d6c715

Barnett, M., & Reid, L. (2020). The effectiveness of methylphenidate in improving cognition after brain injury in adults: a systematic review. *Brain Inj, 34*(1), 1-10. doi:10.1080/02699052.2019.1667538

Beaulieu, C. L., Corrigan, J. D., Bogner, J., Peng, J., Hade, E. M., Montgomery, E., . . . Gilchrist, K. (2021). Quasi-Contextualized Speech Treatment in Traumatic Brain Injury Inpatient Rehabilitation: Effects on Outcomes during the First Year after Discharge. *Journal of Head Trauma Rehabilitation*. doi:http://dx.doi.org/10.1097/HTR.0000000000000649

Bertoni, D., Petraglia, F., Basagni, B., Pedrazzi, G., De Gaetano, K., Constantino, C., & De Tanti, A. (2020). Cognitive reserve index and functional and cognitive outcomes in severe acquired brain injury: A pilot study. *Applied Neuropsychology: Adult*(Advanced Online Publication), 1-11.

Bertoni, D., Petraglia, F., Basagni, B., Pedrazzi, G., De Gaetano, K., Costantino, C., & De Tanti, A. (2020). Cognitive reserve index and functional and cognitive outcomes in severe acquired brain injury: A pilot study. *Applied neuropsychology. Adult*, 1-11. doi:https://dx.doi.org/10.1080/23279095.2020.1804910

Brassel, S., Power, E., Campbell, A., Brunner, M., & Togher, L. (2021). Recommendations for the Design and Implementation of Virtual Reality for Acquired Brain Injury Rehabilitation: Systematic Review. *Journal of Medical Internet Research, 23*(7), e26344-e26344.

Campbell, M. (2000). *Rehabilitation for traumatic brain injury: physical therapy practice in context* (2 ed.): Churchill Livingstone

Cândido, R. C. F., Menezes de Padua, C. A., Golder, S., & Junqueira, D. R. (2021). Immediate-release methylphenidate for attention deficit hyperactivity disorder (ADHD) in adults (Review). *Cochrane Database of Systematic Reviews*(1).

Cantor, J., Ashman, T., Dams-O'Connor, K., Dijkers, M. P., Gordon, W., Spielman, L., . . . Oswald, J. (2014). Evaluation of the short-term executive plus intervention for executive dysfunction after traumatic brain injury: a randomized controlled trial with minimization. *Arch Phys Med Rehabil, 95*(1), 1-9.e3. doi:10.1016/j.apmr.2013.08.005

Castel-Lacanal, E., Tarri, M., Loubinoux, I., Gasq, D., de Boissezon, X., Marque, P., & Simonetta-Moreau, M. (2014). Transcranial magnetic stimulation in brain injury. *Annales Francaises d'Anesthesie et de Reanimation, 33*, 83-87.

Chen, A. J., Novakovic-Agopian, T., Nycum, T. J., Song, S., Turner, G. R., Hills, N. K., . . . D'Esposito, M. (2011). Training of goal-directed attention regulation enhances control over neural processing for individuals with brain injury. *Brain, 134*(Pt 5), 1541-1554. doi:10.1093/brain/awr067

Chen, S. H., Thomas, J. D., Glueckauf, R. L., & Bracy, O. L. (1997). The effectiveness of computer-assisted cognitive rehabilitation for persons with traumatic brain injury. *Brain Inj, 11*(3), 197-209. Retrieved from http://www.ingentaconnect.com/content/apl/tbin/1997/00000011/00000003/art00004?token=005219c73f7f0c5a8405847447b496e2f5f73446f554779663e33757e6f4f2858592f3f3b57d640982

Cicerone, K. D. (2002). Remediation of "working attention" in mild traumatic brain injury. *Brain Inj, 16*(3), 185-195. doi:10.1080/02699050110103959

Cicerone, K. D., Dahlberg, C., Kalmar, K., Langenbahn, D. M., Malec, J. F., Bergquist, T. F., . . . Morse, P. A. (2000). Evidence-based cognitive rehabilitation: recommendations for clinical practice. *Arch Phys Med Rehabil, 81*(12), 1596-1615. doi:10.1053/apmr.2000.19240

Cicerone, K. D., Dahlberg, C., Malec, J. F., Langenbahn, D. M., Felicetti, T., Kneipp, S., . . . Catanese, J. (2005). Evidence-based cognitive rehabilitation: updated review of the literature from 1998 through 2002. *Arch Phys Med Rehabil, 86*(8), 1681-1692. doi:10.1016/j.apmr.2005.03.024

Cicerone, K. D., Langenbahn, D. M., Braden, C., Malec, J. F., Kalmar, K., Fraas, M., . . . Ashman, T. (2011). Evidence-based cognitive rehabilitation: updated review of the literature from 2003 through 2008. *Arch Phys Med Rehabil, 92*(4), 519-530. doi:10.1016/j.apmr.2010.11.015

Cipriani, A., La Ferla, T., Furukawa, T. A., Signoretti, A., Nakagawa, A., Churchill, R., . . . Barbui, C. (2010). Sertraline versus other antidepressive agents for depression. *Cochrane Database of Systematic Reviews, 4*.

Cizman Staba, U., Vrhovac, S., Mlinaric Lesnik, V., & Novakovic-Agopian, T. (2020). Goal-oriented attentional self-regulation training in individuals with acquired brain injury in a subacute phase: a pilot feasibility study. *Int J Rehabil Res, 43*(1), 28-36. doi:10.1097/mrr.0000000000000380

Combs, M. A., Critchfield, E. A., & Soble, J. R. (2018). Relax while you rehabilitate: A pilot study integrating a novel, yoga-based mindfulness group intervention into a residential military brain injury rehabilitation program. *Rehabil Psychol, 63*(2), 182-193. doi:10.1037/rep0000179

Constantinidou, F., Thomas, R. D., & Robinson, L. (2008). Benefits of Categorization Training in Patients With Traumatic Brain Injury During Post–acute Rehabilitation: Additional Evidence From a Randomized Controlled Trial. *Journal of Head Trauma Rehabilitation, 23*(5), 312-328.

Couillet, J., Soury, S., Lebornec, G., Asloun, S., Joseph, P. A., Mazaux, J. M., & Azouvi, P. (2010). Rehabilitation of divided attention after severe traumatic brain injury: a randomised trial. *Neuropsychol Rehabil, 20*(3), 321-339. doi:10.1080/09602010903467746

Cutler, A. J., Suzuki, K., Starling, B., Balakrishnan, K., Komaroff, M., Castelli, M., . . . Childress, A. C. (2022). Efficacy and Safety of Dextroamphetamine Transdermal System for the Treatment of Attention-Deficit/Hyperactivity Disorder in Children and Adolescents: Results from a Pivotal Phase 2 Study. *Journal of Child and Adolescent Psychopharmacology*, 1-9.

Dahdah, M. N., Bennett, M., Prajapati, P., Parsons, T. D., Sullivan, E., & Driver, S. (2017). Application of virtual environments in a multi-disciplinary day neurorehabilitation program to improve executive functioning using the Stroop task. *NeuroRehabilitation, 41*(4), 721-734. doi:10.3233/nre-172183

DeVane, C. L., Liston, H. L., & Markowitz, J. S. (2002). Clinical pharmacokinetics of sertraline. *Clinical pharmacokinetics, 41*(5), 1247–1266.

Donnelly, K. Z., Baker, K., Pierce, R., St Ivany, A. R., Barr, P. J., & Bruce, M. L. (2021). A retrospective study on the acceptability, feasibility, and effectiveness of LoveYourBrain Yoga for people with traumatic brain injury and caregivers. *Disabil Rehabil*, 1-12. doi:10.1080/09638288.2019.1672109

Dubiel, R., Callender, L., Dunklin, C., Harper, C., Bennett, M., Kreber, L., . . . Diaz-Arrastia, R. (2018). Phase 2 Randomized, Placebo-Controlled Clinical Trial of Recombinant Human Growth Hormone (rhGH) During Rehabilitation From Traumatic Brain Injury. *Frontiers in Endocrinology, 9*(520), 1-11.

Dymowski, A. R., Ponsford, J. L., Owens, J. A., Olver, J. H., Ponsford, M., & Willmott, C. (2017). The efficacy and safety of extended-release methylphenidate following traumatic brain injury: a randomised controlled pilot study. *Clinical Rehabilitation, 31*(6), 733-741.

Elbogen, E. B., Dennis, P. A., Van Voorhees, E. E., Blakey, S. M., Johnson, J. L., Johnson, S. C., . . . Beiger, A. (2019). Cognitive Rehabilitation With Mobile Technology and Social Support for Veterans With TBI and PTSD: A Randomized Clinical Trial. *Journal of Head Trauma Rehabilitation, 34*(1), 1-10. doi:10.1097/HTR.0000000000000435

Florentino, S. A., Mohammad, H. B., & Ma, H. M. (2022). Acetylcholinesterase inhibitors to enhance recovery from traumatic brain injury: a comprehensive review and case series. *Brain Injury*.

Fong, K. N. K., & Howie, D. R. (2009). Effects of an Explicit Problem-Solving Skills Training Program Using a Metacomponential Approach for Outpatients With Acquired Brain Injury. *The American journal of occupational therapy : official publication of the American Occupational Therapy Association, 63*(5), 525-534.

Force, D. V. T. B. I. T. (2008). *Report to the Surgeon General: Traumatic Brain Injury Task Force*. Washington, D.C.: Department of Defense and Department of Veterans Affairs

Freeman, M. R., Mittenberg, W., Dicowden, M., & Bat-Ami, M. (1992). Executive and compensatory memory retraining in traumatic brain injury. *Brain Injury, 6*(1), 65-70.

Frenette, A. J., Kanji, S., Rees, L., Williamson, D. R., Perreault, M. M., Turgeon, A. F., . . . Fergusson, D. A. (2012). Efficacy and Safety of Dopamine Agonists in Traumatic Brain Injury: A Systematic Review of Randomized Controlled Trials. *Journal of Neurotrauma, 29*, 1-18.

Gabbatore, I., Sacco, K., Angeleri, R., Zettin, M., Bara, B. G., & Bosco, F. M. (2015). Cognitive Pragmatic Treatment: A Rehabilitative Program for Traumatic Brain Injury Individuals. *J Head Trauma Rehabil, 30*(5), E14-28. doi:10.1097/htr.0000000000000087

Gasco, V., Cambria, V., Bioletto, F., Ghigo, E., & Grottoli, S. (2021). Traumatic Brain Injury as Frequent Cause of Hypopituitarism and Growth Hormone Deficiency: Epidemiology, Diagnosis, and Treatment. *Frontiers in Endocrinology, 12*, 634415.

Ghalaenovi, H., Fattahi, A., Koohpayehzadeh, J., Khodadost, M., Fatahi, N., Taheri, M., . . . Rahatlou, H. (2018). The effects of amantadine on traumatic brain injury outcome: a double-blind, randomized, controlled, clinical trial. *Brain Injury, 32*(8), 1050-1055.

Giggins, O. M., Persson, U. M., & Caulfield, B. (2013). Biofeedback in rehabilitation. *Journal of neuroengineering and rehabilitation, 10*, 60-60. doi:10.1186/1743-0003-10-60

Gonzalez-Portillo, B., Lippert, T., Nguyen, H., Lee, J. Y., & Borlongan, C. V. (2019). Hyperbaric oxygen therapy: A new look on treating stroke and traumatic brain injury. *Brain Cirulation 5*(3).

Gordon, W. A., Zafonte, R., Cicerone, K., Cantor, J., Brown, M., Lombard, L., . . . Chandna, T. (2006). Traumatic brain injury rehabilitation: state of the science. *Am J Phys Med Rehabil, 85*(4), 343-382. doi:10.1097/01.phm.0000202106.01654.61

Goverover, Y., Johnston, M. V., Toglia, J., & DeLuca, J. (2007). Treatment to improve self-awareness in persons with acquired brain injury. *Brain Injury, 21*(9), 913-923.

Gracey, F., Fish, J. E., Greenfield, E., Bateman, A., Malley, D., Hardy, G., . . . Manly, T. (2017). A Randomized Controlled Trial of Assisted Intention Monitoring for the Rehabilitation of Executive Impairments Following Acquired Brain Injury. *Neurorehabilitation and neural repair, 31*(4), 323-333.

Greenwald, B. D., Burnett, D. M., & Miller, M. A. (2003). Congenital and acquired brain injury. 1. Brain injury: epidemiology and pathophysiology. *Arch Phys Med Rehabil, 84*(3 Suppl 1), S3-7.

Hadanny, A., Abbott, S., Suzin, G., Bechor, Y., & Efrati, S. (2018). Effect of hyperbaric oxygen therapy on chronic neurocognitive deficits of post-traumatic brain injury patients: retrospective analysis. *BMJ open, 8*(9), e023387. Retrieved from http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=emexa&AN=624242033

http://vr2pk9sx9w.search.serialssolutions.com/?url_ver=Z39.88-2004&rft_val_fmt=info:ofi/fmt:kev:mtx:journal&rfr_id=info:sid/Ovid:emexa&rft.genre=article&rft_id=info:doi/10.1136%2Fbmjopen-2018-023387&rft_id=info:pmid/30269074&rft.issn=2044-6055&rft.volume=8&rft.issue=9&rft.spage=e023387&rft.pages=e023387&rft.date=2018&rft.jtitle=BMJ+open&rft.atitle=Effect+of+hyperbaric+oxygen+therapy+on+chronic+neurocognitive+deficits+of+post-traumatic+brain+injury+patients%3A+retrospective+analysis&rft.aulast=Hadanny

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6169752/pdf/bmjopen-2018-023387.pdf

Hart, T., Whyte, J., Watanabe, T., & Chervoneva, I. (2018). Effects of dextroamphetamine in subacute traumatic brain injury: A randomized, placebo-controlled pilot study. *Journal of Neuroscience Research, 96*(4), 702–710.

High, W. M., Jr., Briones-Galang, M., Clark, J. A., Gilkison, C., Mossberg, K. A., Zgaljardic, D. J., . . . Urban, R. J. (2010). Effect of growth hormone replacement therapy on cognition after traumatic brain injury. *J Neurotrauma, 27*(9), 1565-1575. doi:10.1089/neu.2009.1253

Hofheinz, M., Mibs, M., & Elsner, B. (2016). Dual task training for improving balance and gait in people with stroke. *The Cochrane Database of Systematic Reviews, 2016*(10), CD012403. doi:10.1002/14651858.CD012403

Holleman, M., Vink, M., Nijland, R., & Schmand, B. (2018). Effects of intensive neuropsychological rehabilitation for acquired brain injury. *Neuropsychol Rehabil, 28*(4), 649-662.

Jacoby, M., Averbuch, S., Sacher, Y., Katz, N., Weiss, P. L., & Kizony, R. (2013). Effectiveness of executive functions training within a virtual supermarket for adults with traumatic brain injury: a pilot study. *IEEE Trans Neural Syst Rehabil Eng, 21*(2), 182-190. doi:10.1109/tnsre.2012.2235184

Jenkins, P. O., De Simoni, S., Bourke, N. J., Fleminger, J., Scott, G., Towey, D. J., . . . Sharp, D. J. (2019). Stratifying drug treatment of cognitive impairments after traumatic brain injury using neuroimaging. *Brain: A Journal of Neurology, 142*(8), 2367-2379. doi:http://dx.doi.org/10.1093/brain/awz149

Jenkins, P. O., De Simoni, S., Bourke, N. J., Fleminger, J., Scott, G., Towey, D. J., . . . Sharp, D. J. (2019). Stratifying drug treatment of cognitive impairments after traumatic brain injury using neuroimaging. *Brain, 142*(8), 2367-2379. doi:10.1093/brain/awz149

Johansson, B., & Tornmalm, M. (2012). Working memory training for patients with acquired brain injury: effects in daily life. *Scand J Occup Ther, 19*(2), 176-183. doi:10.3109/11038128.2011.603352

Johansson, B., Wentzel, A. P., Andrell, P. R., Ronnback, L., & Mannheimer, C. (2017). Long-term treatment with methylphenidate for fatigue after traumatic brain injury. *Acta Neurologica Scandinavica, 135*, 100-107.

Kakehi, S., & Tompkins, D. M. (2021). A Review of Pharmacologic Neurostimulant Use During Rehabilitation and Recovery After Brain Injury. *Annals of Pharmacotherapy, 55*(1254-1266).

Kennedy, M. R., Coelho, C., Turkstra, L., Ylvisaker, M., Moore Sohlberg, M., Yorkston, K., . . . Kan, P. F. (2008). Intervention for executive functions after traumatic brain injury: a systematic review, meta-analysis and clinical recommendations. *Neuropsychol Rehabil, 18*(3), 257-299. doi:10.1080/09602010701748644

Khateb, A., Ammann, J., Annoni, J. M., & Diserens, K. (2005). Cognition-enhancing effects of donepezil in traumatic brain injury. *Eur Neurol, 54*(1), 39-45. doi:10.1159/000087718

Kim, S., Rath, J. F., Zemon, V., Cavallo, M. M., McCraty, R., Sostre, A., & Foley, F. W. (2018). Problem Solving, Biofeedback, and Severe Brain Injury: The Moderating Role of Positive Affect. *Rehabilitation Psychology, 63*(1), 148-154.

Krasny-Pacini, A., Chevignard, M., & Evans, J. (2014). Goal Management Training for rehabilitation of executive functions: a systematic review of effectivness in patients with acquired brain injury. *Disability and Rehabilitation, 36*(2), 105-116.

Kraus, M. F., Smith, G. S., Butters, M., Donnell, A. J., Dixon, E., Yilong, C., & Marion, D. (2005). Effects of the dopaminergic agent and NMDA receptor antagonist amantadine on cognitive function, cerebral glucose metabolism and D2 receptor availability in chronic traumatic brain injury: a study using positron emission tomography (PET). *Brain Inj, 19*(7), 471-479.

Kullberg-Turtiainen, M., Vuorela, K., Huttula, L., Petri, T., & Sanna, K. (2019). Individualized goal directed dance rehabilitation in chronic state of severe traumatic brain injury: A case study. *Heliyon, 5*(2).

Laatsch, L., Pavel, D., Jobe, T., Lin, Q., & Quintana, J. C. (1999). Incorporation of SPECT imaging in a longitudinal cognitive rehabilitation therapy programme. *Brain Inj, 13*(8), 555-570. Retrieved from http://www.ingentaconnect.com/content/apl/tbin/1999/00000013/00000008/art00001?token=00521b85b522afa72297b76504c48664625453a566c787a6a2d356a332b25757d5c4f6d4e227a9e757

Levin, H., Troyanskaya, M., Petrie, J., Wilde, E. A., Hunter, J. V., Abildskov, T. J., & Scheibel, R. S. (2019). Methylphenidate Treatment of Cognitive Dysfunction in Adults After Mild to Moderate Traumatic Brain Injury: Rationale, Efficacy, and Neural Mechanisms. *Front Neurol, 10*, 925. doi:10.3389/fneur.2019.00925

Levine, B., Robertson, I. H., Clare, L., Carter, G., Hong, J., Wilson, B. A., . . . Stuss, D. T. (2000). Rehabilitation of executive functioning: an experimental-clinical validation of goal management training. *J Int Neuropsychol Soc, 6*(3), 299-312.

Lezak, M. D. (2004). *Neuropsychological assessment*. New York: Oxford university press.

Li, K., Alonso, J., Chadha, N., & Pulido, J. (2015). Does Generalization Occur Following Computer-Based Cognitive Retraining?-An Exploratory Study. *Occup Ther Health Care, 29*(3), 283-296. doi:10.3109/07380577.2015.1010246

Liepert, J. (2016). Update on pharmacotherapy for stroke and traumatic brain injury recovery during rehabilitation. *Current Opinion in Neurology, 29*(6).

Lindeløv, J. K., Overgaard, R., & Overgaard, M. (2017). Improving working memory performance in brain-injured patients using hypnotic suggestion. *Brain: A Journal of Neurology, 140*(4), 1100-1106.

Linton, K. F., & Kim, B. J. (2018). A pilot study of Trabajadora de salud, a lay health worker intervention for Latinas/os with traumatic brain injuries and their caregivers. *Disabil Health J, 11*(1), 161-164. doi:10.1016/j.dhjo.2017.04.009

Loggini, A., Tangonan, R., El Ammar, F., Mansour, A., Goldenberg, F. D., Kramer, C. L., & Lazaridis, C. (2020). The role of amantadine in cognitive recovery early after traumatic brain injury: A systematic review. *Clinical Neurology and Neurosurgery, 194 (no pagination)*. Retrieved from http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=emedx&AN=2005429478

https://ocul-uwo.primo.exlibrisgroup.com/openurl/01OCUL_UWO/01OCUL_UWO:UWO_DEFAULT?url_ver=Z39.88-2004&rft_val_fmt=info:ofi/fmt:kev:mtx:journal&rfr_id=info:sid/Ovid:emedx&rft.genre=article&rft_id=info:doi/10.1016%2Fj.clineuro.2020.105815&rft_id=info:pmid/&rft.issn=0303-8467&rft.volume=194&rft.issue=&rft.spage=105815&rft.pages=&rft.date=2020&rft.jtitle=Clinical+Neur

ology+and+Neurosurgery&rft.atitle=The+role+of+amantadine+in+cognitive+recovery+early+after+traumatic+brain+injury%3A+A+systematic+review&rft.aulast=Loggini

Magee, W. L., Clark, I., Tamplin, J., & Bradt, J. (2017). Music Interventions for acquired brain injury. *Cochrane Database of Systematic Reviews*(1).

Maggio, M. G., Maresca, G., De Luca, R., Stagnitti, M. C., Porcari, B., Ferrera, M. C., . . . Calabro, R. S. (2019). The Growing Use of Virtual Reality in Cognitive Rehabilitation: Fact, Fake or Vision? A Scoping Review. *J Natl Med Assoc, 111*(4), 457-463. doi:10.1016/j.jnma.2019.01.003

Man, D. W., Poon, W. S., & Lam, C. (2013). The effectiveness of artificial intelligent 3-D virtual reality vocational problem-solving training in enhancing employment opportunities for people with traumatic brain injury. *Brain Inj, 27*(9), 1016-1025. doi:10.3109/02699052.2013.794969

Martinez-Molina, N., Sinponkoski, S., Kuusela, L., Laitinen, S., Holma, M., Ahlfors, M., . . . Sarkamo, T. (2021). Resting-State Network Plasticity Induced by Music Therapy after Traumatic Brain Injury. *Neural Plasticity, 8*(6682471), 1-18.

Martinez-Molina, N., Siponkoski, S.-T., Sarkamo, T., Kuusela, L., Pekkola, J., Laitinen, S., . . . Cowley, B. U. (2021). Resting-State Network Plasticity Induced by Music Therapy after Traumatic Brain Injury. *Neural Plasticity, 2021*, 6682471. doi:http://dx.doi.org/10.1155/2021/6682471

McDonald, S., & Genova, H. (2021). The effect of severe traumatic brain injury on social cognition, emotion regulation, and mood. In K. M. Heilman & N. S.E (Eds.), *Handbook of clinical neurology* (Vol. 183, pp. 235-260).

McDowell, S., Whyte, J., & D'Esposito, M. (1998). Differential effect of a dopaminergic agonist on prefrontal function in traumatic brain injury patients. *Brain, 121 (Pt 6)*, 1155-1164.

Miller, M. A., Burnett, D. M., & McElligott, J. M. (2003). Congenital and acquired brain injury. 3. Rehabilitation interventions: cognitive, behavioral, and community reentry. *Arch Phys Med Rehabil, 84*(3 Suppl 1), S12-17.

Moreau, O. K., Cortet-Rudelli, C., Yollin, E., Merlen, E., Daveluy, W., & Rousseaux, M. (2013). Growth hormone replacement therapy in patients with traumatic brain injury. *Journal of Neurotrauma, 30*(11), 998-1006.

Napolitano, E., Elovic, E. P., & Qureshi, A. I. (2005). Pharmacological stimulant treatment of neurocognitive and functional deficits after traumatic and non-traumatic brain injury. *Med Sci Monit, 11*(6), Ra212-220.

Narapareddy, B. R., Narapareddy, L., Lin, A., Wigh, S., Nanavati, J., Dougherty, J., . . . Roy, D. (2020). Treatment of Depression After Traumatic Brain Injury: A Systematic Review Focused on Pharmacological and Neuromodulatory Interventions. *Psychosomatics, 61*, 481-497.

Neistadt, M. E. (1992). Occupational therapy treatments for constructional deficits. *Am J Occup Ther, 46*(2), 141-148. Retrieved from http://ajot.aotapress.net/content/46/2/141.full.pdf

Neville, I. S., Zaninotto, A. L., Hayashi, C. Y., Rodrigues, P. A., Galhardoni, R., Ciampi de Andrade, D., . . . Paiva, W. S. (2019). Repetitive TMS does not improve cognition in patients with TBI: A randomized double-blind trial. *Neurology, 93*(2), e190-e199. doi:10.1212/wnl.0000000000007748

Novakovic-Agopian, T., Chen, A. J., Rome, S., Abrams, G., Castelli, H., Rossi, A., . . . D'Esposito, M. (2011). Rehabilitation of executive functioning with training in attention regulation applied to individually defined goals: a pilot study bridging theory, assessment, and treatment. *J Head Trauma Rehabil, 26*(5), 325-338. doi:10.1097/HTR.0b013e3181f1ead2

O'Neil-Pirozzi, T. M., & Hsu, H. (2016). Feasibility and benefits of computerized cognitive exercise to adults with chronic moderate-to-severe cognitive impairments following an acquired brain injury: A pilot study. *Brain Inj, 30*(13-14), 1617-1625. doi:10.1080/02699052.2016.1199906

Oakley, D. A., & Halligan, P. W. (2013). Hypnotic suggestion: opportunities for cognitive neuroscience. *Nat Rev Neurosci, 14*(8), 565-576. doi:10.1038/nrn3538

Passler, M. A., & Riggs, R. V. (2001). Positive Outcomes in Traumatic Brain Injury–Vegetative State: Patients Treated With Bromocriptine. *Archives of physical medicine and rehabilitation., 82*(3), 311-315.

Pavlovic, D., Pekic, S., Stojanovic, M., & Popovic, V. (2019). Traumatic brain injury: neuropathological, neurocognitive and neurobehavioral sequelae. *Pituitary, 22*(3), 270-282. doi:10.1007/s11102-019-00957-9

Powell, J. H., al-Adawi, S., Morgan, J., & Greenwood, R. J. (1996). Motivational deficits after brain injury: effects of bromocriptine in 11 patients. *J Neurol Neurosurg Psychiatry, 60*(4), 416-421. Retrieved from http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1073895/pdf/jnnpsyc00016-0058.pdf

Powell, L. E., Wild, M. R., Glang, A., Ibarra, S., Gau, J. M., Perez, A., . . . Slocumb, J. (2019). The development and evaluation of a web-based programme to support problem-solving skills following brain injury. *Disability and rehabilitation: Assistive technology, 14*(1), 21-32.

Rasquin, S. M., Bouwens, S. F., Dijcks, B., Winkens, I., Bakx, W. G., & van Heugten, C. M. (2010). Effectiveness of a low intensity outpatient cognitive rehabilitation programme for patients in the chronic phase after acquired brain injury. *Neuropsychol Rehabil, 20*(5), 760-777. doi:10.1080/09602011.2010.484645

Rath, J. F., Simon, D., Langenbahn, D. M., Sherr, R. L., & Diller, L. (2003). Group treatment of problem-solving deficits in outpatients with traumatic brain injury: A randomised outcome study. *Neuropsychol Rehabil, 13*(4), 461-488. doi:10.1080/09602010343000039

Reimunde, P., Quintana, A., Castanon, B., Casteleiro, N., Vilarnovo, Z., Otero, A., . . . Devesa, J. (2011). Effects of growth hormone (GH) replacement and cognitive rehabilitation in patients with cognitive disorders after traumatic brain injury. *Brain Inj, 25*(1), 65-73. doi:10.3109/02699052.2010.536196

Sackett DL, S. S., Richardson WS, Rosenberg W, Hayes RB. (2000). *Evidence-based medicine: how to practice and teach EBM* (2nd ed. ed.). Churchill Livingstone, New York.

Sarkamo, T., Huttula, L., Hokkanen, L., Koskinen, S., Leppelmeier, J., Saynevirta, K., . . . Rantanen, P. (2021). DARE to move: feasibility study of a novel dance-based rehabilitation method in severe traumatic brain injury. *Brain Injury, 35*(3), 335-344. doi:http://dx.doi.org/10.1080/02699052.2021.1873420

Schmid, A. A., Miller, K. K., Van Puymbroeck, M., & Schalk, N. (2016). Feasibility and results of a case study of yoga to improve physical functioning in people with chronic traumatic brain injury. *Disability and Rehabilitation, 38*(9), 914-920.

Schmidt, J., Fleming, J., Ownsworth, T., & Lannin, N. A. (2013). Video feedback on functional task performance improves self-awareness after traumatic brain injury: a randomized controlled trial. *Neurorehabil Neural Repair, 27*(4), 316-324. doi:10.1177/1545968312469838

Schneider, W. N., Drew-Cates, J., Wong, T. M., & Dombovy, M. L. (1999). Cognitive and behavioural efficacy of amantadine in acute traumatic brain injury: an initial double-blind placebo-controlled study. *Brain Inj, 13*(11), 863-872. Retrieved from http://www.ingentaconnect.com/content/apl/tbin/1999/00000013/00000011/art00003?token=00541cb6c8bd293d898d383a4b3b2570747b465f41385e572b67732a726e2d2954496f642f466fa656bd

Shin, H., & Kim, K. (2015). Virtual reality for cognitive rehabilitation after brain injury: a systematic review. *J Phys Ther Sci, 27*(9), 2999-3002. doi:10.1589/jpts.27.2999

Siddiqui, S. V., Chatterjee, U., Kumar, D., Siddiqui, A., & Goyal, N. (2008). Neuropsychology of prefrontal cortex. *Indian journal of psychiatry, 50*(3), 202. doi:10.4103/0019-5545.43634

Sigmundsdottir, L., Longley, W. A., & Tate, R. L. (2016). Computerised cognitive training in acquired brain injury: A systematic review of outcomes using the International Classification of Functioning (ICF). *Neuropsychol Rehabil, 26*(5-6), 673-741.

Silveira, K., & Smart, C. M. (2019). Cognitive, physical, and psychological benefits of yoga for acquired brain injuries: A systematic review of recent findings. *Neuropsychol Rehabil*. doi:http://dx.doi.org/10.1080/09602011.2019.1583114

Silver, J. M., Koumaras, B., Chen, M., Mirski, D., Potkin, S. G., Reyes, P., . . . Gunay, I. (2006). Effects of rivastigmine on cognitive function in patients with traumatic brain injury. *Neurology, 67*(5), 748-755. doi:10.1212/01.wnl.0000234062.98062.e9

Silver, J. M., Koumaras, B., Meng, X., Potkin, S. G., Reyes, P. F., Harvey, P. D., . . . Arciniegas, D. B. (2009). Long-term effects of rivastigmine capsules in patients with traumatic brain injury. *Brain Inj, 23*(2), 123-132. doi:10.1080/02699050802649696

Siponkoski, S.-T., Martinez-Molina, N., Sarkamo, T., Koskinen, S., Lipsanen, J., Laitinen, S., . . . Rantanen, P. (2021). Effects of neurological music therapy on behavioural and emotional recovery after traumatic brain injury: A randomized controlled cross-over trial. *Neuropsychol Rehabil*, 1-33. doi:http://dx.doi.org/10.1080/09602011.2021.1890138

Siponkoski, S. T., Martinez-Molina, N., Kuusela, L., Laitinen, S., Holma, M., Ahlfors, M., . . . Sarkamo, T. (2020). Music Therapy Enhances Executive Functions and Prefrontal Structural Neuroplasticity after Traumatic Brain Injury: Evidence from a Randomized Controlled Trial. *J Neurotrauma, 37*(4), 618-634. doi:10.1089/neu.2019.6413

Sisto, S. A., Forrest, G. F., & Glendinning, D. (2002). Virtual reality applications for motor rehabilitation after stroke. *Top Stroke Rehabil, 8*(4), 11-23. doi:10.1310/YABD-14KA-159P-MN6F

Sohlberg, M. M., Avery, J., Kennedy, M., Ylvisaker, M., Coelho, C., Turkstra, L., & Yorkston, K. (2003b). Practice guidelines for direct attention training. *Journal of Medical Speech-Language Pathology, 11*(3), xix-xxxix. Retrieved from http://www.scopus.com/inward/record.url?eid=2-s2.0-0141478707&partnerID=40&md5=154ee5f86521f8e4217df7799c31334b

Sohlberg, M. M., McLaughlin, K. A., Pavese, A., Heidrich, A., & Posner, M. I. (2000). Evaluation of attention process training and brain injury education in persons with acquired brain injury. *J Clin Exp Neuropsychol, 22*(5), 656-676. doi:10.1076/1380-3395(200010)22:5;1-9;ft656

Speech, T. J., Rao, S. M., Osmon, D. C., & Sperry, L. T. (1993). A double-blind controlled study of methylphenidate treatment in closed head injury. *Brain Inj, 7*(4), 333-338.

Spikman, J. M., Boelen, D. H., Lamberts, K. F., Brouwer, W. H., & Fasotti, L. (2010). Effects of a multifaceted treatment program for executive dysfunction after acquired brain injury on indications of executive functioning in daily life. *J Int Neuropsychol Soc, 16*(1), 118-129. doi:10.1017/s1355617709991020

St Ivany, A. R., Bruce, M. L., Donnelly, K. Z., Baker, K., Pierce, R., & Barr, P. J. (2021). A retrospective study on the acceptability, feasibility, and effectiveness of LoveYourBrain Yoga for people with traumatic brain injury and caregivers. *Disability and Rehabilitation, 43*(12), 1764-1775. doi:http://dx.doi.org/10.1080/09638288.2019.1672109

Stephens, J. A., van Puymbroeck, M., Sample, P. L., & Schmid, A. A. (2020). Yoga improves balance , mobility, and perceived occupational performance in adults with chronic brain injury: A preliminary investigation. *Complementary Therapies in Clinical Practice, 40*.

Stubberud, J., Løvstad, M., Solbakk, A. K., Schanke, A. K., & Tornås, S. (2020). Emotional Regulation Following Acquired Brain Injury: Associations With Executive Functioning in Daily Life and Symptoms of Anxiety and Depression. *Frontiers in Neurology, 11*(1011).

Swenson, T. L., Roehmer, C., Tran, R., & Plummer, C. (2021). Donepezil for Aphasia After Severe Traumatic Brain Injury: A Clinical Vignett. *American Journal of Physical Medicine & Rehabilitation*.

The Mayo Clinic. (2019). Hyperbaric Oxygen Therapy. *Patient Care and Health Information.* Retrieved from https://www.mayoclinic.org/tests-procedures/hyperbaric-oxygen-therapy/about/pac-20394380

Tornas, S., Lovstad, M., Solbakk, A. K., Evans, J., Endestad, T., Hol, P. K., . . . Stubberud, J. (2016). Rehabilitation of Executive Functions in Patients with Chronic Acquired Brain Injury with Goal Management Training, External Cuing, and Emotional Regulation: A Randomized Controlled Trial. *J Int Neuropsychol Soc, 22*(4), 436-452. doi:10.1017/s1355617715001344

Tornas, S., Lovstad, M., Solbakk, A. K., Schanke, A. K., & Stubberud, J. (2019). Use It or Lose It? A 5-Year Follow-up Study of Goal Management Training in Patients with Acquired Brain Injury. *J Int Neuropsychol Soc, 25*(10), 1082-1087. doi:10.1017/s1355617719000626

Traeger, J., Hoffman, B., Misencik, J., Hoffer, A., & Makii, J. (2020). Pharmacologic Treatment of Neurobehavioral Sequelae Following Traumatic Brain Injury. *Critical Care Nursing Quarterly, 43*(2), 172-190.

Vanhaudenhuyse, A., Laureys, S., & Faymonville, M. E. (2014). Neurophysiology of hypnosis. *Clinical Neurophysiology, 44*, 343-353.

Vanhaudenhuyse, A., Laureys, S., & Faymonville, M. E. (2015). The use of hypnosis in severe brain injury rehabilitation: a case report. *Acta Neurol Belg, 115*(771-772).

Vas, A. K., Chapman, S. B., Cook, L. G., Elliott, A. C., & Keebler, M. (2011). Higher-order reasoning training years after traumatic brain injury in adults. *J Head Trauma Rehabil, 26*(3), 224-239. doi:10.1097/HTR.0b013e318218dd3d

Whyte, J., Vaccaro, M., Grieb-Neff, P., Hart, T., Polansky, M., & Coslett, H. B. (2008). The effects of bromocriptine on attention deficits after traumatic brain injury: a placebo-controlled pilot study. *Am J Phys Med Rehabil, 87*(2), 85-99. doi:10.1097/PHM.0b013e3181619609

Winters Fisher, A. F. (2019). Dance/movement therapy & warrior wellness: A pilot case study. *Arts in Psychotherapy, 62*, 52-60. Retrieved from http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=emexa&AN=2001636363

https://ocul-uwo.primo.exlibrisgroup.com/openurl/01OCUL_UWO/01OCUL_UWO:UWO_DEFAULT?url_ver=Z39.88-2004&rft_val_fmt=info:ofi/fmt:kev:mtx:journal&rfr_id=info:sid/Ovid:emexa&rft.genre=article&rft_id=info:doi/10.1016%2Fj.aip.2018.11.010&rft_id=info:pmid/&rft.issn=0197-4556&rft.volume=62&rft.issue=&rft.spage=52&rft.pages=52-60&rft.date=2019&rft.jtitle=Arts+in+Psychotherapy&rft.atitle=Dance%2Fmovement+therapy+%26+warrior+wellness%3A+A+pilot+case+study&rft.aulast=Winters+Fisher

Wong, D., Sinclair, K., Seabrook, E., McKay, A., & Ponsford, J. (2017). Smartphones as assistive technology following traumatic brain injury: a preliminary study of what helps and what hinders. *Disability and Rehabilitation, 39*(23), 2387-2394.

Zhang, W. T., & Wang, Y. F. (2017). Efficacy of methylphenidate for the treatment of mental sequelae after traumatic brain injury. *Medicine, 96*(25), e6960.