The Study of Cognitive Rehabilitation Effectiveness

The SCORE clinical trial is a randomized controlled treatment trial evaluating the effectiveness of cognitive rehabilitation in post-deployment military service members who sustained a concussion.

Chapter 3: Computerized Cognitive Rehabilitation Interventions for Persistent Symptoms Following Mild Traumatic Brain Injury (SCORE Arm 2)

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Congress established DVBIC in 1992 after the first Gulf War in response to the need to treat service members with TBI. DVBIC's staff serves as the Defense Department's primary TBI subject matter experts. DVBIC is part of the U.S. Military Health System and is the TBI operational component of the Defense Centers of Excellence for Psychological Health and Traumatic Brain Injury (DCoE). Learn more about DVBIC at dvbic.dcoe.mil.

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SCORE Disclaimer

Chapter 3: Computerized Cognitive Rehabilitation Interventions for Persistent Symptoms Following Mild Traumatic Brain Injury (SCORE Arm 2)

By Anne E. Bunner, Ph.D.; Henry W. Mahncke, M.D.; Catherine N. Stasio; Amy O. Bowles, M.D.; Christy Muncrief, CTRS; Michelle A. Lindsay, ANP-BC; and Douglas B. Cooper, Ph.D., ABPP-CN

Introduction

The past decade has seen rapid growth in the development of computer-based interventions to improve cognitive functioning. These interventions have been employed in a variety of patient populations, including traumatic brain injury (TBI),[1] aging,[2,3] and severe psychiatric conditions.[4]

Significant advantages to using computer-based interventions in a post-deployment population of active duty service members and veterans include cost, access, potential scalability, and the ubiquity of technology use in the young adult age cohort. Consequently, the Study of Cognitive Rehabilitation Effectiveness (SCORE) study team designed a treatment arm of the clinical trial for participants with a history of mild TBI that was aimed specifically at providing computerized cognitive rehabilitation (CR) intervention. This treatment arm is known as Arm 2.

This chapter will provide a brief overview of the underlying concepts of brain plasticity, a review of computerized cognitive intervention studies with TBI patients, a description of the BrainWorks™ computer-based intervention used in SCORE, and methodological details including administrative and technical information regarding Arm 2.

Basics of Brain Plasticity

Brain plasticity refers to the brain's lifelong capacity for physical and functional change. The concept of brain plasticity is more than a century old,[5] and has been the subject of active investigation for several decades. While brain plasticity has been most often discussed in the contexts of early child development or injury recovery, the capacity for physical and functional brain change is believed to exist in all people, regardless of age or health status. The premise underlying cognitive training programs is that training can help improve general cognitive performance and enhance the readiness of the brain to engage in cognitively demanding work, provide stronger resilience to injury, and support faster recover from injury by promoting changes in brain machinery.

Brain plasticity experiments have documented a number of important means by which progressive learning changes brain machinery.[6]

According to Mahncke et al.:

> Research in this field has demonstrated that the adult brain continuously adapts to disproportionately represent relevant sensory stimuli and behavioral outputs with well-coordinated populations of neurons. This adaptation is achieved by engaging competitive processes in brain networks that refine the selective representations of sensory inputs or motor actions, typically resulting in increased strengths of cortical resources devoted to, and enhanced representational fidelity, or precision, of the learned stimulus or behavior.[7]

Classic examples of plasticity include violin players who have been shown to have stronger and more distinct representations of the fingers in the right hemisphere, which correspond to the individuated finger movements required by their left hands,[8] and taxi cab drivers with enlarged hippocampi, reflecting their experience with spatial navigation.[9] These examples illustrate how exquisitely elaborated and highly differentiated cortical representations develop in the learning of any highly skilled behavior. Such brain changes, if induced broadly across brain systems, could lead to better cognitive performance, improved readiness for challenging cognitive work, and greater resilience to mild brain damage.[10,11]

Review of Computerized Cognitive Rehabilitation Interventions for TBI

Although the phenomenon of brain plasticity is well-documented, evidence supporting the effectiveness of computer-assisted cognitive rehabilitation following TBI is limited. In 2014, an international group of researchers and clinicians known as INCOG (an acronym for "international cognitive") published several clinical recommendations regarding cognitive rehabilitation, each of which focused on a separate cognitive domain. Regarding attention and information processing speed, the authors concluded that decontexualized computer-based attentional task practice is not recommended due to lack of evidence of generalizable benefit.[12] In their literature review, the authors found mixed evidence of efficacy, with most positive results occurring on neuropsychological measures as opposed to everyday activities. Similarly, an INCOG review of memory rehabilitation stated that no current evidence supported the efficacy of computer-based interventions for restoring memory or enhancing sustained memory performance. However, the recommendation expressed that there may be potential benefit when computer training is combined with instructional support (e.g., therapist coaching) and compensatory strategies.[13]

Nonetheless, preliminary evidence demonstrates some capacity for self-administered computerized CR to improve neuropsychological and neurobehavioral outcomes. A pilot feasibility study by Lebowitz et al. evaluated an in-home computer-assisted cognitive training program used by community-dwelling participants with TBI history. The design and sample size (n = 10) prohibited analysis of efficacy, but results of neurocognitive testing and self-reported symptoms scales showed a trend towards improved executive function following 6 weeks of training, consisting of approximately five 40 minute sessions per week.[14] These results suggest that self-administered computer-assisted cognitive training programs are feasible treatment components with potential benefits.

The Brain Fitness Center at the Walter Reed National Military Medical Center offers computerized cognitive rehabilitation in a structured environment. Researchers conducted a retrospective examination of 29 consecutive patients with pre- and post-treatment assessment data to evaluate effectiveness of computerized training. Pre-and post-treatment assessments with the Mayo-Portland Adaptability Inventory-4 (MPAI-4) and the Neurobehavioral Symptom Inventory (NSI) showed significant reductions in symptom severity, but no significant changes in the Satisfaction with Life Scale (SWLS).[1] Despite the varied treatment protocol used in this pilot study, the findings indicate the potential efficacy of computer-assisted cognitive rehabilitation.

A randomized controlled trial by Twamley et al. included 34 participants with mild to moderate TBI history. The study evaluated a computerized cognitive intervention (Cognitive Symptom Management and Rehabilitation Therapy, or CogSMART) in the context of supported employment. After 12 weeks of rehabilitation, the experimental group showed significantly greater improvements in the NSI than participants in a control group, who received enhanced supported employment.[15] No other significant differences between groups were observed in neuropsychological test performance, posttraumatic stress disorder (PTSD) or depression symptom severity, quality of life, or employment-related outcomes. Non-significant improvements were observed in prospective memory performance, PTSD and depression symptoms, and return to competitive employment within 14 weeks. Results suggested that adding CogSMART to supported employment may improve post-concussion symptom and memory outcomes.[15]

A pilot study by Tam et al. investigated computer-assisted memory rehabilitation outcomes in 26 closed TBI patients with short-term semantic memory impairment. Participant groups used four different memory training strategies in 10 sessions of 20-30 minutes each. All four intervention groups and the no-intervention group showed non-significant improvements in the Rivermead Behavioral Memory Test (RBMT),[16] findings that may have been influenced by the small size of the groups or the relatively short intervention duration. A subsequent study using a one month intervention with computer-assisted memory training included 37 patients with mild to severe TBI. Intervention group participants showed significant improvements in the RBMT when compared with control participants who received no memory training.[17]

Existing literature shows that computerized CR may have potential for improving some TBI-related outcomes. However, current understanding is limited by a lack of well-controlled studies. The significant gaps in knowledge regarding computerized CR contributed to the SCORE team's motivation to include a computerized CR intervention as a component of the SCORE trial.

BrainWorks™

BrainWorks™ is a web-based cognitive training software package developed by Posit Science and was a predecessor of the commercially available BrainHQ.[18] This program was selected as the computer-based intervention for Arm 2 in SCORE for several reasons. Chiefly, a number of clinical studies with similar software developed by Posit Science have shown promising results. The pilot study by Lebowitz et al. described above demonstrated that the software was usable and well-rated among participants with a history of TBI. In addition, Posit Science software has been found to be effective in samples of older adults[2,19-24] and has shown promise in a variety of conditions where cognitive symptoms are a consequence of underlying brain damage or dysfunction, including chemotherapy, human immunodeficiency virus (HIV), schizophrenia, and stroke patients.[25-31] Finally, BrainWorks™ was available online, which made the intervention usage highly feasible for the SCORE trial.

The BrainWorks™ software package includes 10 distinct cognitive training exercises using visual and auditory stimuli. Exercises target processing speed, working memory, attention, learning, and reasoning (see Table 3.1). Each exercise employs a carefully designed stimulus set that allows progressive training of speed and accuracy within the domain of that exercise. The stimulus set is also designed to span the relevant dimensions of real-world stimuli, with the intent that learning is not stimulus specific (i.e., that it may generalize beyond the task trained to real world conditions). In addition, the stimulus set is designed to use decontextualized stimuli in early training to drive synchronized brain responses, and progressively move to more ecologically relevant stimuli to facilitate generalization to the real-world situations.

To progress through an exercise, the participant must perform increasingly difficult discrimination, recognition or sequencing tasks under conditions of close attentional control. Each exercise uses sophisticated adaptive tracking methods to continuously adjust a single adaptive dimension of the task to the sensory and cognitive capabilities of the participant. The exercises rapidly adapt to an individual's performance level, and maintain the difficulty of the stimulus sets at an optimal level for engaging efficient learning.

Using BrainWorks™ in a Group Setting

This section provides a description of administrative aspects of the computerized treatment arm (SCORE Arm 2), as well as technical considerations for implementing the treatment arm in a military treatment facility.

Administrative Aspects of the Computerized CR Intervention

All SCORE participants received the standard of care, which included education (see Chapter 2) and symptom-based medical management consistent with the VA/DoD Clinical Practice Guideline for the Management of Concussion/Mild Traumatic Brain Injury (mTBI).[32]

To maintain consistency with other SCORE treatment arms, Arm 2 participants received CR intervention in a structured setting with equivalent intensity (10 hours per week). Participants engaged in computer training for 2 hours each weekday, completing exercises in a proctored computer laboratory setting that consisted of up to 12 computer stations. Proctors scheduled make-up sessions for missed appointments to ensure that participants completed assigned training hours.

The proctor provided instruction on the use of the program and how to maneuver through the site to complete all tasks, and supplied positive encouragement for participation in the treatment. The proctor also provided assistance if an error or problem developed with the computer system. Apart from these interactions, there was minimal involvement between proctor and participant. The proctor was unable to see the participant's performance on individual computer tasks. Participants selected the computerized intervention tasks from a predetermined menu, but neither the proctor nor other study personnel instructed or recommended a set course of treatment.

The SCORE study team selected exercises in conjunction with experts at Posit Science before the initiation of the research trial, targeting specific domains (see Table 3.1). The computer program automatically regulated difficulty levels, speed, intensity, and duration. As part of the self-directed design of the Arm 2 CR intervention, participants chose the order of the specific cognitive modules. Once participants completed the content in a specific cognitive treatment module, that module was no longer available to the participant at login. These modules were presented to participants in the context of a game (BrainWorks™) in an interactive format that incorporated in-program rewards.

Table 3.1. Cognitive Treatment Modules

Cognitive Treatment Module	BrainWorks™ Game Name	Sensory Modality	Domain
Auditory Time Order Judgment	Test Driver	Auditory	Speed of Processing Verbal Working Memory
Phoneme Discrimination	Navigator	Auditory	Speed of Processing Verbal Working Memory
Auditory Sequence Reconstruction	Audio Mash-Up	Auditory	Verbal Learning
Auditory Spatial Match	Coffee Break	Auditory	Verbal Working Memory Attention
Auditory Instruction Sequence	Set Crew	Auditory	Verbal Working Memory Attention
Auditory Narrative Memory	BrainWorks™ Blog	Auditory	Verbal Working Memory Attention
Useful Field of View	Speed Trap	Visual	Speed of Processing Attention
Multiple Object Tracking	Pet Wrangler	Visual	Visual Working Memory Attention
Response Selection and Suppression	Stock Trader	Visual	Reasoning
Categorization	Online Shopper	Visual	Reasoning

Technical Aspects of the Computerized CR Intervention

All participants enrolled in the Arm 2 CR intervention used the internet-based BrainWorks™ program. The Brooke Army Medical Center (BAMC) information technology staff, who managed the entire computer system, used a non-Department of Defense (DoD) commercial network for greater security and ease of operation. The system consisted of the following:

- Virtual desktops hosted on two stand-alone servers for redundancy
- Windows XP operating system for the virtual hosts
- Minimum capacity of 21 concurrent virtual hosts on the virtual servers

The BAMC information technology staff dropped non-DoD commercial network cables into a conference room that had been configured into a "computer lab," with cardboard desk dividers between participant stations. Each station had a laptop computer engineered to allow access only to the BrainWorks™ website content through the Google Chrome internet browser. SCORE participants randomized to other treatment arms used the same laptop computers to complete their homework sessions for traditional and integrated cognitive rehabilitation. The homework tasks, which included mindfulness online audio files and the computerized Attention Process Training module 3 (APT-3), were hosted on both servers and available through the virtual desktop (see Chapters 4 and 5 for more details). Participants used over-the-head stereo headphones for the audio tasks.

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Appendix A: Acronyms

APT-3	Attention Processing Training, module 3
BAMC	Brooke Army Medical Center
CR	cognitive rehabilitation
CogSMART	Cognitive Symptom Management and Rehabilitation Therapy (computerized CR program)
DoD	Department of Defense
HIV	human immunodeficiency virus
INCOG	"International cognitive" – An international group of researchers and clinicians issuing clinical recommendations regarding cognitive rehabilitation
MPAI-4	Mayo-Portland Adaptability Inventory-4
NSI	Neurobehavioral Symptom Inventory
PTSD	posttraumatic stress disorder
RBMT	Rivermead Behavioral Memory Test
SCORE	Study of Cognitive Rehabilitation Effectiveness
SWLS	Satisfaction with Life Scale
TBI/mTBI	traumatic brain injury/mild traumatic brain injury