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REVIEW ARTICLE

Cognitive Rehabilitation Improves Performance of Individuals with Mild to Moderate Traumatic Brain Injury: A Review of Comprehensive Neuropsychological Services as a Model Approach

***Cheryl A Frye*[1,2,3,4,5*]*, Anton Hardy*[5,6]*, and Maria Lifrak*[5,7]

[1]*Department of Psychology, The University at Albany, USA*
[2]*Biological Sciences, The University at Albany, USA*
[3]*Centers for Neuroscience, The University at Albany, USA*
[4]*Life Sciences Research, The University at Albany, USA*
[5]*Comprehensive Neuropsychological Services, State University of New York, USA*
[6]*Veteran's Affairs Support Services, State University of New York, Saratoga, USA*
[7]*Department of Counseling Psychology, The University at Albany, USA*

***Corresponding author:** *Cheryl A Frye, Ph.D, Professor of Psychology, Department of Psychology, The University at Albany, 1400 Washington Ave Albany, NY 12222, USA, Tel: 1-518-322-8058*

Abstract

Traumatic Brain Injuries (TBI) can result in physical, cognitive and emotional symptoms and the constellation of sequelae that can linger for years and is termed post-concussion syndrome (PCS). For these ailments, therapy is available to help individuals recover; however, it is controversial whether cognitive rehabilitation can improve or forestall lost or damaged abilities. It is important to clarify this because insurances companies can be reluctant to pay for this treatment. To test the efficacy of cognitive rehabilitation, 6 women with mild traumatic brain injury consented to participate in this experiment. Each person was administered attention processing training, number search, visual memory and find the shape tasks, over a period of 4.4-6.8 months and the latencies and accuracies for each participant on each trial was measured. There was a significant reduction in latencies and improvements in accuracy from before training to after training with an effect size of greater than 2.0. Together, these data show that 6 months of cognitive rehabilitation significantly and robustly improved performance in all patients.

Keywords

Traumatic brain injury, Concussion, Cognitive rehabilitation, Attention, Memory

The Efficacy of Cognitive Rehabilitation for Individuals with Mild Traumatic Brain Injuries

Traumatic brain injury (TBI) is the leading cause of disability and is the number one cause of death in young adults. Approximately 2.5 million people sustain a (TBI) and present at an emergency room annually in the United States, of which 11% result in morbidity and/or mortality. These epidemiological data do not include those treated in federal facilities (military base, Veteran's facility, prison), urgent care facilities, private doctors' offices or those who do not seek care. Blunt force trauma to the head from slipping and falling, car accidents, sports injuries, work accidents, domestic violence, and sports injuries are some common ways individuals acquire his/her TBI [1,2].

Traumatic brain injuries are diagnosed by the presence of symptoms that were not pre-existing prior to the TBI. Many people believe that if there are not changes visible using an imaging technique, such as a CAT scan or MRI it means they do not have a TBI. This is false. More than 90 percent of patients presenting to the emergency department with mild TBI or concussion have a negative CT scan. These imaging techniques are

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not sensitive enough to detect the shearing of brain cells that occurs in mild TBI. Scans using spectrophotometry and function can often pick this brain changes but are typically not offered as an option. Given that the brain controls the body, and different parts of the brain control different physical, cognitive and/or emotional functions, up to 140 symptoms have been associated with mild TBI (see list in pamphlet produced by Brent Feuz) [3]. Because of the plethora of symptoms, and a sudden change in the capacity and self-identity, many people don't seek medical attention after a TBI. One minute they were one person (before the injury) and after the injury they are someone else. This trauma of loss of self can prevent people from seeking care and is the basis for much psychopathology. Mild-moderate TBI brings other adverse side effects, including physical, cognitive and emotional challenges and medical trauma. This may include mild to moderate aphasia, visual problems, short and long-term memory problems, increased physical pain levels, frequent headaches and migraines, confusion, seizures, and mood disorders, such as depression and anxiety. In the absence of neurological evidence, only neuropsychologists can diagnose TBIs, based upon symptomatology and performance on standardized neuropsychological testing.

In 1980, Dr. Maria Lifrak opened Comprehensive Neuropsychological Services in Albany New York. She was trained in the 1960's as a school psychologist. She subsequently spent much time at West Point, as an Officer's wife raising their children. She saw firsthand, the consequences of TBI. She thought a type of occupational therapy for the brain, based on targeting different areas of function, customized to brain areas damaged, and behaviors needed to improve, would be helpful. She sought out additional training at Yale, working with individuals with intractable seizures (congenital rather than acquired TBI). She would administer the WADA test, which then was the cutting-edge technique to ascertain the hemisphere of an individual that controls the language areas of the brain. This was used to identify and avoid harming these areas during psychosurgery to help mitigate epilepsy [4].

With this additional training, she opened what at the time was a unique business. At her side was Dr. Anton Hardy, who had worked at the New York State Center for Mental Hygiene for years prior. The data presented in this paper is literally that of their first clients. Drs. Lifrak and Hardy were strong believers in evidence-based practice before that was a buzz-word. They did not want to be using techniques that were not proven. Also illustrating their foresight, they have had every single patient sign an agreement that his/her results (or product or their cognitive rehabilitation) can and would be used in teaching and research and would be the property of the practice.

The hypothesis of this work is that cognitive rehabilitation will be beneficial for individuals who recently suffered a mild traumatic brain injury. As a way to measure the effectiveness of these specific treatment methods, a longitudinal study was performed, in which participants' latencies and accuracy were measured before and after exposure to cognitive rehabilitation that met the combination of their needs.

One kind of cognitive rehabilitation that is typically universally needed after a mild or moderate TBI is for attention. Attention refers to how one receives and processes internal and external information. Attention deficits after TBI, include problems in sustained attention/concentration, delayed reaction time, distractibility, decreased processing speed, and impaired dual or multitasking (e.g., walking and talking). Attention can be improved significantly with a specific skill training after acquired brain injury which target five components of attention: Focused attention, sustained attention, selective attention, alternating attention, and divided attention. The training program consists of tasks with a hierarchical progression of increasing attention demands, graduating from simple to complex distracters [5]. It is one of the first skills lost and that can return among TBI patients.

Methods

Comprehensive neuropsychological services

The group of patients used in this study is the first six women, who were in need of cognitive rehabilitation, who presented at Comprehensive Neuropsychological Services (CNS). As a result, the rehabilitative tasks chosen were those that would benefit all of the patients.

Consent

All 6 individuals who participated in this study gave verbal and written consent for use of her scores for publication, research, or training purposes. NB: This was years before the health insurance portability and accountability act (HIPAA).

Participants

The first 6 patients at CNS (age range: 24-54 years, mean age = 32.5 years, mean education = 14.5 years) were used to be a part of the study. The 6 patients used in this study, suffered mild traumatic brain injured from motor vehicle accidents. The average number of months the participants received cognitive rehabilitation is 5.10 months.

Attention processing training

Attention processing training is a widely acclaimed technique used in cognitive therapy. Based on extensive research conducted to evaluate its significance and validity, results show that this particular technique targets difficulties with information processing and concentration. With consistent administration to individuals who suffer from cognitive deficits, attention processing training is

shown to improve cognitive abilities, specifically attention and mental processing. A study conducted by Sohlberg and Mateer, 2008 elucidate the significant improvements in attention participants in their study made following the administration of attention processing training for 5-10 weeks. This therapeutic technique can be administered at a slow speed or fast speed. Both are used in this study. At either speed, patients are evaluated on their selective attention and sustained attention. All of the techniques utilized herein are based on the following premises and methods [5-7].

Attention Process Training (ATP) Tapes- Slow Speed are used to enhance sustained and selective auditory attention abilities. Tapes 1-8 are designed to improve sustained attention ability. Tapes 9-16 are designed to improve selective attention ability. The directions are given at the start of each tape and the patient is required to tap each time she identifies a target on the tape. This requires the patient to hold and manipulate information in their hands. When the APT Tapes are used to enhance sustained and selective auditory attention abilities and speed of mental processing. (From: Attention Process Training. McKay Moore Sohlberg, and Catherine A. Mateer, Ph.D.)

Number search

The Number Search is a technique administered to enhance a patient's attention, visual scanning abilities, short-term memory, and speed in which they process information [7]. The computer with 4 areas labeled A-D. Numbers 1-28 are randomly placed within the 4 boxes. The patient must identify in which area each sequential number is located. This visual memory exercise can be used with simple (3 × 3) or complex (4 × 4) displays depending upon the abilities of an individual. The program is also designed to show more than one display without warning the patient in advance, which is to be recalled. The length of time used to complete this task is measured by the computer, as are percentage of correct answers. (From: KLS Cognitive Educational System. Produced by Lambert Software Company. Portions copyrighted by Microsoft Corp, 1981).

Find the shape

The find the shape technique is used in cognitive rehabilitation to enhance attention and concentration, visual discrimination, visual scanning and speed of mental processing. A series of geometric shapes are displayed in 5 rows. One of the shapes will be selected as the target shape and will be displayed at the top of the screen. The objective is to count all the shapes that match the target shape as quickly as possible. The length of time used to complete this task is measured by the computer, as are percentage of correct answers.

Statistical analyses

The results of each of the tests above were compared at the outset of testing before cognitive rehabilitation and after cognitive rehabilitation using a two-tailed paired t-test with an alpha cronbach value of 0.01. If the results of the t-test were significantly different from performance before cognitive rehabilitation and after, for latencies and accuracies, they were considered to be improved.

Statistical Results of paired two tailed T-tests comparing group performance at time 1 and at the last performance. The alpha value was set at $p < 0.01$, the threshold probability for rejecting the null hypothesis, an indication of type I error rate. The β threshold was set at 0.200, the probability of failing to reject the null hypothesis under the alternative hypothesis, an indication of type II error rate. Given the small number of participants, we set the effect size criteria standard high at 1.0. Reaching this criterion would mean there would be at least 84% difference and 55% non-overlap between start and finish, which would demonstrate a large and potent interventions in a small sample [8,9].

Results

The performance of each individual improved significantly following cognitive rehabilitation. Details regarding performance on each task and statistical significance are indicated below and in Table 1.

Attention processing training

For the Attention Processing Training slow technique, there was a statistically significant reduction in latencies

Table 1: Statistical Results of paired two tailed T-tests comparing group performance at time 1 and at the last performance. The alpha value was set at $p < 0.01$, the threshold probability for rejecting the null hypothesis, an indication of type I error rate. The β threshold was set at 0.200 Probability of failing to reject the null hypothesis under the alternative hypothesis, an indication of type II error rate. The mean is the difference between pre and post-performance. The standard deviations is based upon the underlying outcome measurement, assumed to be the same at both time points, and within-subject correlation of the outcome. See: http://www.sample-size.net/effect-size-study-paired-t-test/. The effects sizes are all well beyond 2.0 indicating there was less than 3% overlap between the scores at the first time measured and the second. The effect seizes here demonstrate the potent interventions utilizes that produced such big have bigger effect sizes in a small sample [9].

Test	Degrees of Freedom	Significance Level	Mean (secs)	Standard Deviation	T-Value	Effect Size
APT Slow	1,5	0.01	-1.52	22.01	2.109	46.427
APT Fast	1,5	0.01	-5.54	132.09	4.032	278.626
Visual Memory	1,5	0.01	-49.12	7975.88	5.166	16824.049
Number Search	1,5	0.01	-45.08	2401.01	4.032	5064.588
Find the Shape	1,3	0.01	-3.53	65.20	5.841	242.566

and errors between performance before and after cognitive rehabilitation. The average time to complete the slow and fast tasks was reduced by an average of nearly 2 and 6 secs, respectively (Table 1). Those with traumatic brain injuries tapped with greater errors of omission and commission, at the start of the slow or fast tape than at the end (data not shown).

Number search

Results from the number search task show a 55 sec reduction in the average time it took for patients to complete the task post-cognitive rehabilitation compared to initial performance. After receiving cognitive rehabilitation, it is evident that the patients improved. With the goals set for the number search task, patients' visual scanning, mental processing, attention and concentration improved significantly. Cognitive rehabilitation improved performance among all individuals.

Visual memory

Observations from the results of the visual memory scores show there was a 45 second decrease in the responses after receiving cognitive rehabilitation when compared to the latencies to respond pre-cognitive rehabilitation. Participants with traumatic brain injury are not expected to get a high percentage of correct responses before receiving any form of cognitive rehabilitation. However, the percentage was able to increase, showing progress in their recovery, as well as progress in visual memory and concentration skills. Visual memory training enhanced performance among all 6 individuals.

Find the shape

For the find the shape technique, we observed the average time in seconds it took for participants to complete the task. Unlike the other techniques, only 5 of the 6 participants received this as part of their cognitive rehabilitation plan, due to attrition. The number of participants showing an overall decline in seconds to complete these tasks was reduced in 4 of 5 individuals.

Discussion

Results from the study are consistent with the hypothesis that attention-based cognitive rehabilitation is beneficial for people with recent traumatic brain injuries. For the attention processing training slow technique, all 6 participants had a decrease in number of errors. The same results are reflected in the attention processing training fast technique. Even though both versions of the training technique were administered at different speeds, patients were able to decrease the number of incorrect taps between their first assessment and last assessment. This illustrates the improvement in attention and processing speed. The Number Search task saw the most significant progress for all participants. This in turn may show that number search is better at working attention, memory and concentration for people with traumatic brain injuries. The visual memory exercise saw overall improvements in correct answers for all 6 patients. With the purpose of the task being to improve visual memory and concentration, all 6 patients were able to advance their cognitive abilities. Although there was one fewer patient who performed significantly better in the shape task, all but one was able to decrease the number of seconds it takes to complete the task.

The results stress the importance of immediate attention based cognitive rehabilitation for individuals with mild traumatic brain injuries. The mission wasn't just to show how effective the different tasks are. It was to display how cognitive performance can be improved when tasks are chosen appropriate to the individuals' immediate need for rehabilitation. In 5-6 months, the patients, who were each skeptical she could improve, showed excellent strides in her cognition. Combining these 5 techniques demonstrated improvements in memory, attention, concentration, and speed of mental processing, which are essential assets to functional cognitive performance and are typical deficits in people with traumatic brain injury.

Limitations of this study include other variables that should have been taken into consideration. The first limitation is there was no control group in this study. This is a criticism of most studies evaluating cognitive rehabilitation because of not wanting to withhold a potential therapeutic value. Second, the severity of participants' cognitive deficiencies was not taken into consideration, just the timing, immediate need. The first patients presenting were used. Some patients may have performed better in memory tasks like find the shape or number search because the severity of the cognitive difficulties is mostly with concentration and mental processing. A third limitation is performance on pre-assessment and post-assessment should be included each test day. A sheet measuring the participants' pain levels, mental fuzziness, hours of sleep from the previous night, tinnitus levels, and headache levels should have been provided for the start and end of sessions. It should have been taken into consideration how the client was feeling for these assessments, which may have affected their scores. Now, we monitor patients' symptoms in between sessions with their reporting symptomatology via a computer system and have been working on the development of a symptom reporting application as is available for seizures and other conditions. The next steps should be measuring performance after the cessation of cognitive rehabilitation to ascertain if this causes regression in cognitive abilities. However, there are obvious ethical challenges with this as indicated above. Future studies would address the limitations stated above to show the efficacy of cognitive rehabilitation for individuals with traumatic brain injuries.

For Lifrak and Hardy, who were fastidious and rigorous clinician scholars, demonstrating that their use of cognitive rehabilitation unequivocally helped individuals with mild traumatic brain injuries was integral to the start of their practice and helping others with similar deficits. Their results, nearly 40 years ago, did show how valuable cognitive rehabilitation is for individuals with mild traumatic brain injuries and led them on to grow a vibrant, stable and unique practice. Comprehensive Neuropsychological Services has gone on to provide psychological services and cognitive rehabilitation to over 2500 individuals, who have sustained mild or moderate brain injury. Comprehensive Neuropsychological Services also aids clients with post-concussion syndrome, neurotoxicity, stroke, dementia, multiple sclerosis, anoxia, seizure disorder, brain tumors and other central nervous system disorders. Comprehensive Neuropsychological Services fosters a safe and supportive environment where patients learn about their physical, cognitive, and emotional status and to cope effectively. Adjusting to the consequences of brain injury is difficult and requires the support of multiple mental health professionals who are knowledgeable about brain functioning and injury and coordinate their care with the patient, family and other providers. Therefore, CNS' program attends not only to the individual's specific cognitive impairments, but to the emotional, social, medical, and financial components of his or her condition.

Cognitive rehabilitation at CNS uses various computerized programs, memory exercises, skill-building strategies, and games, such as math card games or board games, to engage clients in their treatment. It is important for the clinic to evaluate where each client is experiencing their deficits in order to create a unique treatment plan that focuses on rebuilding these skills. In addition to fun and educational activities, our cognitive rehabilitation program also focuses on everyday functional training, such as learning how to count money or how to read again. These strategies can help a brain-injured client regain simple occupational behaviors that are a necessity in their everyday life.

Many studies show that cognitive rehabilitation is not effective. A meta-analysis in the Lancet in 2009 of 90 studies pretty much summarizes the nay-sayers and this author is in complete agreement with their evaluation. Some of the features of programs that do not work are as follows. Programs that do not consider where the brain injury is, functions that are needed, and use rehab to gain back those function are less effective. Program that uses a one-size fits all approach do not work well. Programs that do not meet each individual patient where they are less effective. Laurie Shaw, a Cognitive Rehab Specialist at CNS stated, "we meet our patient in the boat, wherever it is, and help them row". Features of effective programs would be those that involve monitoring, collection of data regularly, have treatment plans and a higher ratio of providers to non-professionals. Regrettably, one facility in our area that recently closed its doors with little notice, had a director and was largely run by support staff using a one size fits all cafeteria method. They could not keep up financially even using this approach because of the limited numbers of insurance companies that support cognitive rehabilitation for minor TBI. More people need cognitive rehabilitation, than there are qualified providers; however, most insurance companies do not provide support for cognitive rehabilitation for mild-moderate TBI because of lack of data to support its benefits. If cognitive rehabilitation providers could demonstrate treatment plans and convincing arguments that their approaches worked, more insurance company may be willing to support therapy for those with mild-moderate TBI. Most insurance companies in our region do not readily provide support for cognitive rehabilitation for mild TBI. However, the consensus is that the sooner a person with TBI can get attention-based rehab the more affective it can be [10].

In 2014, Dr. Lifrak, knowing I had returned early from a 2-3 year mission to enhance biomedical research and health care delivery in my home state of Alaska, invited me to her practice. Interestingly, there were totems of the tribe of 4,400 individuals I affiliate with. It did not take me much more for me to agree to assist Drs. Lifrak and Hardy with their practice until I returned to UAlbany from my leave. I assisted them in updating things in my role as a research associate, while I underwent retraining, as I had not actively engaged in neuropsychological work for 25 years. I regret I had only 2 and 4 years respectively to work with Drs. Lifrak and Dr. Hardy, before their passings. The good news is that the transition of CNS was almost seamless for the clientele. This is due to the tireless efforts of the business manager, Donna Mease, who has been at CNS for over a decade.

In one of my current roles, Director of CNS, I have continued and reinforced many of the practices. First, evidence-based practice continues to be emphasized. There is a theme or reading for each week, that is part of educating patients and practioners about TBI. Much of this has to do with how to tap into neurogenesis in areas of the brain that are damaged. The initial research on neuroplasticity was conducted to understand how the brain develops from birth until early adulthood; however, continued research on neuroplasticity shows that growth of new neuronal tissues is possible in adults, not just in children, in areas of the brain that involve learning, memory and affect. We use proven techniques of environmental enrichment to tap into neurogenesis, such as aromatherapy, light, and exercise (yoga). We encourage familial, social and sexual relations at home that improve brain function and neurogenesis. Second, there is no question that the immediate environment plays a large role. The facility has been completely

updated to be more simple, relaxing, hygienic, and to emphasize features of nature in this beautiful home built in the 1880's. Patients are made comfortable with blankets and couches for napping as needed, as well as refreshments. There are two waiting rooms at CNS. One that can be closed off if a person needs to time out and sleep. The other is adjacent. People often talk there, on the veranda, or in the gardens that have been re-architectured, per Dr. Hardy's original design. Third, CNS is now much more than a doctor's office. It has become a retreat for people with TBI. People come to their appointments early to get out of the house and limit their social isolation and talk to others with a TBI. There are more group sessions and people have also requested monthly group outings to reduce the loneliness and isolation that comes along with this disorder, which will enhance neurogenesis.

Because of the past success of their approach, CNS has thousands of patient records that are being analyzes for factors associated with recovery from TBI. Preliminary data show all other things being equal, those who had more roles a priori, engaged in cognitive rehab sooner and more rigorously, were discharged earlier with a better prognosis. We have currently observed a pattern for total cholesterol signaling to be elevated with recovery from mild to moderate TBI and believe this is due to its production as a building block for trophic factors for repair.

The physical and cognitive impairment caused by brain injuries can be reduced with cognitive rehabilitation [9]. In a study on cognitive rehabilitative strategies, it is stressed that different techniques, as well as other forms of treatments, are beneficial approaches to repairing cognitive insufficiencies. Techniques used in cognitive rehabilitation target memory, speech concentration, and attention. With consistent quality sessions, it is possible for someone to improve their cognitive abilities and recover from a situation, such as a brain injury. It is an exciting period to be working in cognitive rehabilitation now that biomarkers, such as GFAP may be available [11]. Further, studies have demonstrated that cognitive therapy can change the structure of the brain using fMRI [12]. I look forward to guiding CNS into the future and continuing my ongoing research on effects and mechanisms of neuroendocrine factors involved in the etiopathophysiology and treatment of social, cognitive, affective aspects of neurodegenerative disorders, such as TBI [13].

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