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An Overview of the Use of Neurofeedback Biofeedback for the Treatment of Symptoms of Traumatic Brain Injury in Military and Civilian Populations

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ABSTRACT

Background: Neurofeedback, a type of biofeedback, is an operant conditioning treatment that has been studied for use in the treatment of traumatic brain injury (TBI) in both civilian and military populations. In this approach, users are able to see or hear representations of data related to their own physiologic responses to triggers, such as stress or distraction, in real time and, with practice, learn to alter these responses in order to reduce symptoms and/or improve performance.
Objective: This article provides a brief overview of the use of biofeedback, focusing on neurofeedback, for symptoms related to TBI, with applications for both civilian and military populations, and describes a pilot study that is currently underway looking at the effects of a commercial neurofeedback device on patients with mild-to-moderate TBIs.
Conclusions: Although more research, including blinded randomized controlled studies, is needed on the use of neurofeedback for TBI, the literature suggests that this approach shows promise for treating some symptoms of TBI with this modality. With further advances in technology, including at-home use of neurofeedback devices, preliminary data suggests that TBI survivors may benefit from improved motivation for treatment and some reduction of symptoms related to attention, mood, and mindfulness, with the addition of neurofeedback to treatment.

Keywords: traumatic brain injury, TBI, biofeedback, neurofeedback, EEG, mindfulness

INTRODUCTION

Traumatic brain injury (TBI), which can range from mild to severe, is a prevalent problem in both military and civilian populations.[1] The Centers for Disease Control and Prevention estimates that more than 280,000 hospitalizations and 2.2 million emergency department visits are associated with a TBI diagnosis in 1 year. TBI can lead to permanent disability when survived.[2] In the U.S. military, 22,681 service members were diagnosed with a first-time TBI in 2015 alone, according to the Defense and Veterans Brain Injury Center,[3] with TBI being referred to as the ''signature wound'' in veterans of the Iraq and Afghanistan deployments.[4] In both civilian and military populations, these estimates are often thought to be low, as TBI can be underreported and/or misdiagnosed, given some symptoms

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can also mimic or overlap with symptoms of other diagnoses such as post-traumatic stress disorder (PTSD).[5–7]

TBI symptoms, presentation, and recovery can vary greatly, depending on the severity of the injury, part(s) of the brain that are injured, and type of injury sustained, among other factors.[1,8] Symptoms can include headaches, mood changes, fatigue, and memory issues, as well as problems with attention and concentration, and have been shown to affect satisfaction with life; this also occurs in veteran populations.[5] Although a percentage of survivors of TBIs become disabled as a result, Davis, et al.[9] cites a 2009 review by McCrea, et al.,[10] which stated that—at least in the case of a single mild TBI (mTBI) without complications—the large majority of cases have complete recovery within days to weeks.

Patients, including military personnel, who do continue to suffer from symptoms longer-term also can struggle with finding effective treatments to address their symptoms.[1,11,12] Medical providers, medications, physical therapy, occupational therapy, speech language therapies, and behavioral health professionals can all play vital roles in the recovery from a brain injury, but even the most effective therapies are sometimes not enough to resolve residual symptoms in some TBI survivors. Given the complexity of this injury and its impact on the lives of people who are affected by it, new treatments and modalities are being sought to address related symptoms of TBI and improve quality of life for survivors.

BIOFEEDBACK

One such modality is biofeedback, which is an umbrella term for a number of treatments that use operant conditioning to help patients become more aware of their own physiologic responses in real time and, with practice and feedback, learn to control these once-automatic responses better in order to reduce symptoms, improve performance, and/or increase well-being.[12–14] Various types of physiologic measures (including surface temperature, heart rate variability [HRV], surface electromyography [sEMG; i.e., muscle tension], galvanic skin response [GSR; i.e., skin conductance], and electroencephalography [EEG; i.e., neurofeedback]) are used, either singly or together, to transmit data to the user, usually via visual and/or audio displays, while the user is guided by a trained clinician.[12–14] Reinforcements—such as controlling elements of a computer game based on physiologic changes—help train users to become more aware of their physiologic responses to emotional, cognitive, or physical stimuli, and to gain more control over these responses, with an ultimate goal of being able to generalize this ability to in-vivo settings.

Psychotherapies, such as cognitive–behavioral therapy (CBT) or mindfulness-based therapies might also be used in conjunction with biofeedback directly to affect thought patterns and coping skills that could be playing negative roles in symptom etiology and/or perpetuation. With this newfound awareness and active practice via these techniques, users can learn to alter the behaviors, habits, patterns, and responses that are contributing to the maintenance of symptoms or inhibiting performance or function.[12–14]

For example, in patients with symptoms, such as headaches or attention problems following a brain injury, a sample biofeedback protocol could involve a general stress and relaxation assessment, using multiple types of biofeedback, including devices that measure surface muscle tension (e.g., sEMG), surface temperature, HRV, breathing rates via the use of a respiration belt, skin conductance/ GSR, and/or brainwaves via EEG. The assessment would measure the patient's response to stressors—such as solving math problems out loud, or recalling an emotionally stressful event, or having to pay close attention to a detail-oriented task—as well as the patient's ability to recover from these stressors and evoke a relaxed state. This information could then be used to determine any abnormal or exaggerated responses that might be contributing to symptoms and that might warrant training with biofeedback treatment sessions.

Subsequent sessions then focus on the use of one or more modalities to alter physiology in ways that reduce symptoms and/or improve performance. A clinician may choose to use sEMG biofeedback, for example, to measure the muscle tension in the frontalis (forehead area) or trapezius (shoulder area) muscles to see if excess tension caused by stress and/ or poor body mechanics may be contributing to, or exacerbating, headache pain. The patient would gradually be taught to become more aware of areas and causes of tensions and then to reduce muscle tension by way of various relaxation techniques and/or correct body positioning, which would then be generalized to everyday situations for ongoing maintenance and prevention.[8,12,13]

The use of biofeedback in general for symptoms related to TBI often varies depending on the type, severity, symptomatology, and duration of the brain injury, as well as other factors, such as the clinician's training and access to specific types of biofeedback equipment, patient preferences, and insurance limitations.[4,8,12–14] There are also varied protocols and approaches to using the many types of biofeedback, many of which are used in combination with more than one form of biofeedback concurrently, and are also often used in conjunction with other forms of therapy, such as CBT.[4,8,12–15] Furthermore, patients might also be receiving a number of additional treatments at the same time as biofeedback, such as medications, cognitive rehabilitation therapies, physical therapy, and general psychotherapy, as well as potentially experiencing ongoing or ''spontaneous'' recovery over the time following the injury, in addition to having comorbid diagnoses or symptoms that mimic those associated with TBI (e.g., attention-deficit hyperactivity disorder or PTSD).[1,7,8,12–14,16]

Therefore, the heterogeneity related to both the injury and to biofeedback as a treatment can add to challenges in making conclusions about the efficacy of this approach from the research literature, and there needs to be more blinded, randomized, controlled trials with identified protocols using biofeedback for the treatment of symptoms of TBI in both civilian and military populations.[4] However, in a review of research on the efficacy of biofeedback in general for various medical conditions, TBI was listed as having a ''Level 3; Probably Efficacious'' efficacy rating on an Association for Applied Psychophysiology and Biofeedback scale that spanned from Level 1 (''Not empirically supported'') to Level 5 (''Efficacious and specific).[14] Although the rating does not delineate which types and severity levels of TBI were studied, nor does it list which specific types of biofeedback or protocols were indicated for TBI at this level of evidence, it is likely that much of this research was pulled from the use of EEG biofeedback for the treatment of TBI, as this has been a prominently researched area in the field of biofeedback in recent years.[4,12,14,17]

NEUROFEEDBACK

As noted above, the use of EEG biofeedback (i.e., neurofeedback)—while not the only form of biofeedback used to treat symptoms of TBI—has evolved technically and in practice to become a common and promising choice for the treatment of TBI in the field of biofeedback by measuring outputs and patterns of the organ that has been injured and comparing them to associated cognitive states and processes.[4,12,13,17–26] The EEG, which records electrical activity of the brain over time, was introduced in 1929 and was shown to respond to volitional control via operant conditioning by 1962.[12,18,27]

More recently, with the corresponding technological advances computers provided, quantitative EEG, which digitizes the EEG signal, has been introduced as the newer generation of EEG neurofeedback. This allows for more clinical sensitivity and specificity, although protocols and use of the equipment can vary from practitioner to practioner.[4,12,18,27–29] EEG patterns have been shown to be different in individuals following TBI, and have even been shown to predict prognosis in some cases.[7,12,26,27] Side-effects from neurofeedback can include headaches, nausea, dizziness, fatigue, and agitation.[18] These are common symptoms that TBI survivors seek to mitigate that might be worsened by the use of a computer screen to provide feedback, which can exacerbate symptoms in some patients with brain injuries. At least 1 researcher has suggested that, for this reason, other forms of biofeedback or relaxation training, or the use of audio feedback versus computer-based visual feedback, may be suited better to patients who are early in their TBI recovery and/or more sensitive to the effects of a computer screen on their symptoms.[26]

As with other forms of biofeedback, the principles of helping train users to become more of aware of the patterns that might be contributing to symptoms and/or interfering with performance or health, and learning to change these patterns by receiving audio, visual, and/or sensory feedback in real time, is the same. The number of sessions required in order to achieve positive change may range from 5 to 60, sometimes involving more than 1 session per week to help generalize skills and improve outcomes.[28] The patient may be guided to help increase attention or concentration, with neurofeedback patterns observed in real time, or helped to decrease activity in certain areas by utilizing relaxation techniques, for example, which correlate with patterns associated with healthy functioning, and are thought to contribute to neural plasticity as a mechanism of training.[18]

Although the research still lacks a large body of randomized, double-blinded, placebo-controlled studies following standardized protocols, the literature does suggest that survivors—in both civilian and military populations—of brain injuries of differing levels of severity report improvements across a wide range of complaints of problems with attention, impulse control, processing speed, short-term memory, and mood.[4,8,12–15,17–29] Research on the use of neurofeedback for veteran populations has often focused on its use when PTSD or substance abuse is comorbid with TBI from blast injuries, with significant improvements reported, once the original protocol was modified.[18,28] Generalizability from the research is complicated by not only the lack of randomized, double-blinded, placebo-controlled studies following standardized protocols, but also by the variety of types and causes of TBIs. For example, in a military population alone, injuries may come from a motor vehicle accident, a fall, a blast injury in which the energy of the blast may affect neuronal functioning, or an injury that involves a blow to the head—each of which can occur on different parts of the brain, at different levels of severity, and which might require different types of treatment approaches for the best outcomes.

PILOT STUDY ON NEUROFEEDBACK FOR TBI

In recent years, with advances in technology and the ability to use ''dry sensor'' electrodes to pick up and digitize EEG signals, neurofeedback devices have been developed that appeal to a population interested in relatively affordable, home-use, ''wearable'' devices as a way to monitor and improve well-being and performance.

One such device is the Muse (InteraXon, Inc., SCR_014418, Toronto, Ontario, Canada) neurofeedback device, which is advertised as a ''brain fitness tool that measures brain signals.'' It has seven dry sensors on a lightweight headband to detect and measure brain activity at specific points across the forehead and behind the ears; the device then uses that data to provide auditory feedback to the user as a way to ascertain states of calmness and alertness in real time via an app. The program utilizes mindfulness-based guided meditation exercises to help the user learn to evoke states of calmness over more alert or distracted states, and tracks progress so that the users can view their scores over time as they practice and earn ''rewards'' for longer periods of calmness as measured by the device. At least one initial study on the use of this device in a healthy adult population showed modest benefits for attention and subjective well-being, compared to an active control group.[30] The device has been used with veteran populations, but no studies on its use with service members have been published at present (R. Lanius, personal communication).

Although mindfulness meditation on its own has been shown to have promising results in relation to some TBI symptoms,[31–33] the addition of this device and its mindfulness app with a brain-injured population had not yet been studied. The author and her colleagues, at Harvard Medical School and Spaulding Rehabilitation Hospital, are currently conducting a pilot study of 20 patients with chronic mild-to-moderate TBIs comparing a group utilizing the Muse neurofeedback device and a group receiving the same mindfulness meditation intervention via the app without the use of the device to see if there is a benefit in this population on measures of attention, mood, and mindfulness when using this device. Participants are assessed using neuropsychologic measures before and after the 6-week intervention of daily meditation practice, and are interviewed at the end for subjective feedback. Compliance in both groups is tracked via their logins through the app and via self-reporting.

DISCUSSION

The preliminary data gathered so far in this ongoing study suggest that some of the psychologic variables—such as measures of anxiety, depression, self-efficacy, and mindfulness—are trending toward improvement in both groups. Some neuropsychologic variables—such as divided attention and executive attention—might also be trending toward improvement, although this could be a practice effect. The percentage of time that the Muse device measured participants in a ''calm'' phase has improved mildly in both groups (with the meditation-only group being measured on the device at the end of the study).

However, the Muse groups have shown greater time spent practicing on their own, above and beyond the required daily intervention, which might suggest increased motivation and consistency with this group, potentially due to the feedback provided by the device. The qualitative responses by the participants seem to echo this possibility, with many participants in the Muse group commenting on the value of the structure and ''objective results'' provided by the Muse program, with 1 participant noting that having the Muse device was ''more helpful than just saying 'go home and meditate.' I find I need more direction since the [brain] injury.'' Some participants, however, found the feedback from the Muse app distracting rather than helpful, or did not notice a correlation between the feedback and the state of calm they perceived themselves to be in at the time, which did not allow them to associate states of calm with the feedback in real time, thereby inhibiting the goal of biofeedback in general. Although the study is still ongoing, initial data are suggesting some quantitative and qualitative differences between the groups, which will be analyzed more robustly at the study's completion.

CONCLUSIONS

Neurofeedback, a type of biofeedback, shows promise in initial research studying its efficacy for treatment of symptoms of TBI. Biofeedback may provide a more concrete, structured approach that might appeal to some populations and/or personality types than others, although the cost of the treatment and equipment, along with the potential for some computer-based interventions to exacerbate symptoms in patients with TBI, may need to be weighed against the potential benefits. Although more research, including blinded randomized controlled trials, is needed on the use of biofeedback—and neurofeedback in particular for TBI—the literature suggests that this approach shows promise for treating some symptoms of TBI with this modality. With further advances occurring in technology, including at-home use of neurofeedback devices, preliminary data from the pilot study suggests that survivors of TBI could benefit from improved motivation for treatment and some reduction of symptoms related to attention, mood, and mindfulness with the addition of neurofeedback to mindfulness meditation training. Additional research is needed on the use of neurofeedback, including at-home devices, with veteran populations with brain injuries and should screen for comorbid conditions such as PTSD.

AUTHOR DISCLOSURE STATEMENT

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