Reducing surgical residents' burnout using neurofeedback

Study measures results of medical workers' depression before and after treatment

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In recent years, changes in the healthcare industry have increased scrutiny on financial productivity, quality of care, patient safety and care outcomes taking away autonomy from clinicians. It is no surprise that national studies suggest that burnout and depression rates among surgeons range from 30% to 38% and have increased over the past five years to more than 50% ("Multiple Institution Comparison of Resident and Faculty Perceptions of Burnout and Depression During Surgical Training," Michael L. Williford, Sara Scarlet, Michael O. Meyers, et al, *JAMA Surgery*, 2018).

Burnout is a stress-related syndrome and is characterized by emotional exhaustion, depersonalization and a decreased sense of personal accomplishment. The prevalence of burnout and depression are greater among residents than among medical students, physicians or college graduates of similar age. Furthermore, surgical residents with high burnout and depression are at an increased risk for suicidal ideation.

Training of surgical residents involves complex and demanding cognitive activities including multitasking, clinical reasoning, problem-solving and overall information processing, all of which results in high cognitive workload. Studies suggest that cognitive workload is impaired in burnout and/or depressed residents exposed to high task demands. Therefore, surgical residents with burnout or depression are more likely to commit medical errors that can lead to patient safety issues, including patient harm.

To optimize cognitive workload, neurofeedback protocols are being increasingly used in diverse fields, including healthcare. Neurofeedback is a scientifically based technique that allows the brain to train its self-regulation skills. The process is based on operant conditioning and it is often described as "exercise for the brain" that increases the efficiencies of specific brain functions and enhances cognitive skills.

To date, no previous work has investigated the efficacy of neurofeedback protocols in improving cognitive workload, performance and symptoms of burnout and depression in surgical residents. We herein present the results of an innovative pilot study intended to assess the impact of neurofeedback on the cognitive workload of surgery residents with burnout and depression. Notable improvements in cognitive workload and growth areas following the neurofeedback treatment were recorded, suggesting a possible return to less burnout condition.

Methods used in the study

From June to August 2018, 15 surgical residents with burnout – a Maslach Burnout Inventory (MBI) score of more than 27 – and depression – a Patient Health Questionnaire-9 Depression Screen (PHQ-9) score of more than 10 – from one academic institution were enrolled and participated in this institutional review board (IRB) approved prospective study. Ten residents with more severe burnout and depression scores were assigned to a neurofeedback treatment, and five others were treated as controls.

Each participant's cognitive workload (or mental effort) was assessed initially, and again at an eight-week interval, via electroencephalogram (EEG) with the oscillatory power recorded while the subjects performed a computerized n-back working memory task. This task, a widely used measure for the assessment of working memory function, involved indicating when a current stimulus (a picture) matched the one from n steps earlier in a sequence (e.g., "1-n" requires that participants had to remember the picture presented one image previously, and so on). It used E-Prime software, with an inter-stimulus interval of 1,500 milliseconds and stimulus presentation time of 500 ms, while seated in front of a computer in a sound and light attenuated room, at 72 degrees Fahrenheit.

The treatment consisted of eight validated alpha-theta neurofeedback sessions, each 35 minutes long, during the eight-week interval. The alpha-theta protocol was divided into two separate periods: 1) Pz alpha/theta training period (eyes closed, deep relaxation for 24 minutes) with the inhibit frequencies set to 2-4 hertz (Hz) and 15-30 Hz and the reward frequencies set to 5-7 Hz and 8-11 Hz; and 2) C5 beta awakening/arousal period to ensure proper mental activation before releasing participating residents back to the clinical work areas (eyes open for nine minutes) with the inhibit frequencies for beta C5 training set at 1-12 Hz and 20-30 Hz and the reward frequencies set to 15-18 Hz. Throughout the neurofeedback periods, the impedance was maintained below 10 kiloohm.

Overall, each session began with instructions for the participants to remain relaxed and still for approximately 20 to 40 seconds as BrainPaint neurofeedback software gathered baseline measures for the reward and inhibit frequencies. Next, participants were instructed to perform their "best" to maintain their cognitive state for deep relaxation during alpha/theta protocol as guided by the respective reward frequencies. No specific instructions were provided for the awaking/arousal period.

During both periods, when rapid increases in the 1-12 Hz and 22-30 Hz frequency ranges were 30% greater than the amplitudes recorded during the baseline period, participants were notified by the software via verbal and visual feedback about potential excessive movement or muscle tension. EEG recordings were made on a BrainVision Recorder, with BrainAmp 32 channel system sampled at 500 Hz filtered online between 0.16 and 100 Hz, then were preprocessed and analyzed in EEGLAB and with Matlab scripts. All EEG data were pre-processed and analyzed by an expert cognitive scientist with specific expertise in EEG data processing using custom EEGLAB and Matlab scripts. Data were downsampled to 256 Hz and independent component analysis (ICA) was run to help identify and remove artifacts (e.g., eye blinks) and segmented around stimuli by type from -4 to 4s. Analysis of variance (ANOVA) with parametric bootstrapping tested for significance between the degree of change (pre- vs. post-) in the treatment and control groups. All P values were two-sided, with P < .05 deemed significant.

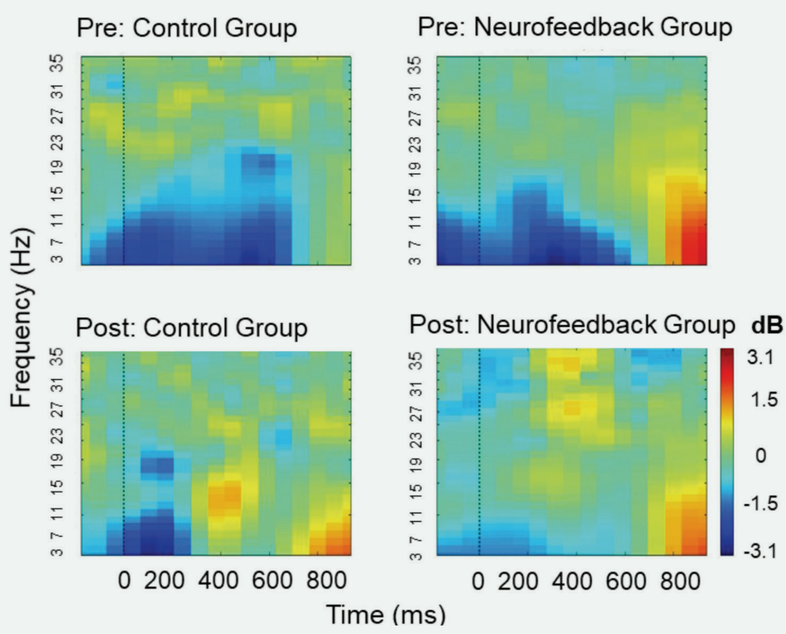
In addition, to proactively mitigate study risks, we asked each participant to report daily on their overall status (e.g., amount and quality of sleep, feeling of being depressed, thoughts of suicide). Participants used a four-point scale ranging in general from better than yesterday, same as yesterday, average, worse than yesterday, to one of the worst days ever. Participants were also asked to identify three to four specific growth areas in which they would like to improve over the eight-week period (e.g., concentration on task, stress levels, temper, overall energy), using the learnings from the neurofeedback sessions.

Thus, starting with second session, participants reported progress using a -100 to +100 absolute scale for each selected growth area. For each session, we averaged these absolute differences in scores to generate a composite score reflecting the overall perceived progress by the intervention group on their individualized growth areas. With this data, we analyzed for the correlation between the time (sessions) and average absolute improvements in growth areas as reported by the participants.

FIGURE 1

Neurofeedback, before and after

Overall EEG power per time (x-axis) and frequency (y-axis) for the n-back target stimuli during the pre- and post-assessments in the control and treatment groups.



Results from neurofeedback sessions

Figure 1 demonstrates overall EEG power per time (x-axis) and frequency (y-axis) for the n-back target stimuli during the pre- and post-assessments in the control and treatment groups. Both groups show relatively high cognitive workload in the pre-assessment, with somewhat inefficient theta (8-11 Hz) and alpha (12-15 Hz) activity (represented by more dark blue color).

After the neurofeedback intervention, the treatment group showed a significant ($p < 0.01$) improvement in cognitive workload during the working memory task with changes in EEG oscillatory theta and alpha power. These differences were not noted in the control group.

Throughout the study, we experienced only two instances when two different participants reported concerning trends in their feeling of depression and were immediately contacted by an experienced psychiatrist to intervene as needed. Fortunately, no major interventions were needed, and in both cases participants were allowed to continue with the study protocol. Participants also reported significant improvements in the growth areas – significant correlation between time (sessions) and absolution improvements in growth areas ($p < 0.01$).

In this study, there was a notable change in cognitive workload following the neurofeedback treatment, suggesting a return to a more efficient neural network. To the best of our knowledge, this is the first study in surgical residents to demonstrate improvements in cognitive workload as quantified via brain EEG patterns following a neurofeedback treatment.

In all 15 subjects, initial baseline activity exhibited relatively inefficient cognitive workload, especially as represented by theta (8-11 Hz) and alpha (12-15 Hz) activity. Such a pattern, while hypothetical in residents with burnout, is worrisome and could reflect the need to recruit additional cognitive resources to complete the working memory task.

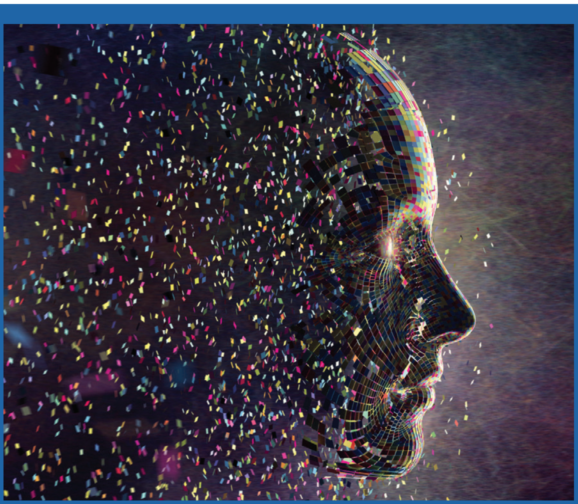
For example, quantitative EEG studies, while not focusing on cognitive workload, suggest that inefficient theta (8-11 Hz) and alpha (12-15 Hz) activity is associated with posttraumatic stress disorder and elevated theta is associated with impaired working memory performance in patients with PTSD. Empirical evidence from prior randomized control trials and multiple pilot/exploratory studies demonstrates the effectiveness of neurofeedback in the treatment of PTSD – e.g., significant symptom improvement compared with controls; 70% of participants in the treatment group not meeting the diagnostic criteria for PTSD following the neurofeedback treatment ("EEG-Neurofeedback as a Tool to Modulate Cognition and Behavior: A Review Tutorial," *Frontiers in Human Neuroscience*, Stefanie Enriquez-Geppert, Rene J. Huster, Christoph S. Herrmann, 2017). There were also notable improvements in growth areas, suggesting tangible benefits to participants.

For example, one subject reported improvement in quality of time with family and children: "I noticed that on the days with neurofeedback secession to have better interaction with my family. For example, last week I was calmer with my children and quality time was much better. My short fuse was longer."

Another participant reported control over self-regulation of negative thoughts: "Neurofeedback made me more conscious of my internal feelings and provided me with more self-control. This allows me to put my head in the right space. Also, it helps me relax faster."

However, not all participants directly benefited from this study. One participant reported the following: "Neurofeedback was a good opportunity to be mindful. Disconnecting and meditative aspect was helpful. However, I noted no specific changes in my selected growth areas. I still have trouble focusing on the task, my mind wonders a lot and I have a hard time falling asleep."

This exploratory study has several limitations. First, the results are based on one experiment with few subjects and without a "sham" neurofeedback control group. Given the extensive training needed in the study (eight neurofeedback



The 6 types of brain waves

Brain wave speed is measured in hertz (cycles per second) and divided into bands delineating slow, moderate and fast waves. Here are descriptions for the different types of brain waves:

Infra-low (below 0.5 Hz). Infra-low brain waves, also known as slow cortical potentials, are thought to be the basic cortical rhythms that underlie higher brain functions. Their slow nature makes them difficult to detect and accurately measure.

Delta (0.5 to 3 Hz). Deltas are slow, loud brain waves, low frequency and deeply penetrating like a drum beat. They are generated in deepest meditation and dreamless sleep. Delta waves suspend external awareness and are the source of empathy. Healing and regeneration are stimulated in this state.

Theta (3 to 8 Hz). Thetas occur in sleep and are also dominant in deep meditation. They are the gateway to learning, memory and intuition. It is that twilight state experienced as we wake or drift off to sleep.

Alpha (8 to 12 Hz). Alpha brainwaves are dominant during quietly flowing thoughts, and in some meditative states. Alpha is the resting state for the brain and aids overall mental coordination, calmness, alertness, mind/body integration and learning.

Beta (12 to 38 Hz). Beta brainwaves are present in our normal waking state of consciousness when attention is directed toward cognitive tasks and the outside world. Beta is a present when we are alert, attentive, engaged in problem-solving, judgment, decision-making or focused mental activity. Beta waves are further divided into three bands: Lo-Beta or Beta 1 (12-15 Hz), a "fast idle;" Beta 2 (15-22 Hz) high engagement; and Hi-Beta or Beta3 (22-38 Hz) highly complex thought, anxiety or excitement.

Gamma waves (38 to 42 Hz). The fastest of brain waves relate to simultaneous processing of information from different brain areas. Gamma waves pass information rapidly and quietly.

Source: *brainworksneurotherapy.com*

sessions, 35 minutes each in length over an eight-week period), only a modest number of participants could receive the treatment. Such is often common in these types of studies.

Second, nonrandom allocation of subjects led to an intentional higher level of initial burnout-depression in the treatment group, thus raising the possibility that they had a larger potential to improve.

Nevertheless, the significant improvement in cognitive workload following the neurofeedback treatment suggests that this innovative approach warrants further evaluation as a potential intervention to address burnout-depression concerns for surgery residents.

Future studies could also examine the degree to which burnout and depression symptoms in surgical residents correlate with specific alterations in EEG or other neural activation patterns, as well as behavior outcomes. ❖

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