Neurofeedback: An inside perspective

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How much would you pay to improve your brain? What if you had problems of attention, depression, or anxiety—would you pay even more to rewire your brain and overcome your condition? For a few thousand dollars, many brain-training practitioners claim to provide this service. Using a technique called *neurofeedback*, they present individuals with a live feed of their own brain activity. By watching our brain, neurofeedback advocates argue that we can learn to regulate its activity and, in turn, control our behavior. The relevant data, however, reveal a more nuanced story. One of placebos.

In this chapter, we focus on the most popular neurofeedback modality and the only one applied clinically: electroencephalography neurofeedback, or simply EEG-nf. Our perspective comes from the angle of a former neurofeedback coach, and current neuroscientist (Ghaziri), and a cognitive neuroscientist who has extensively reviewed the EEG-nf literature (Thibault). Together, we argue that EEG-nf may help improve some conditions, but, at least in the way it is currently applied, this technique relies almost exclusively on placebo effects and psychoeducation (providing support and information to help people cope with their condition).

On the surface, EEG-nf looks like an advanced biomedical therapy. Practitioners sit patients down, apply electrodes to their scalp, and provide a simple auditory and/or visual cue to let participants know when their brain is "performing well." Depending on the patient's condition, positive feedback will stem from different brainwave frequencies. In psychological terms, EEG-nf uses operant conditioning to reward and train-specific brainwave patterns. Patients generally train for 30−60 minutes at a time and often return for up to 40 sessions. Where EEG-nf diverges most from standard-of-care biomedicine is in the subpar research on which it rests.

Although over 3000 research publications discuss EEG-nf, only 11 experiments meet the standard of clinical research: double-blind and placebo-controlled. In the

Casting Light on the Dark Side of Brain Imaging. DOI: https://doi.org/10.1016/B978-0-12-816179-1.00019-0

case of EEG-nf, a proper placebo control entails a "sham" feedback signal, often taken from the recordings of a previous participant [1]. Only one of these 11 studies, which aimed to rehabilitate stroke patients, showed a superiority of genuine over sham neurofeedback in terms of behavioral outcomes. Most of the other 10 experiments attempted to improve attention deficit hyperactivity disorder (ADHD) and demonstrated equivalent improvement between the experimental and control groups. Somewhat counterintuitively, the United States Food and Drug Administration (FDA) allows neurofeedback devices. Yet, only to promote relaxation. The FDA considers all other uses of neurofeedback as "off-label." Even then, the FDA never "approved" EEG-nf. Instead, EEG-nf squeezed through a grandfather loophole where any device in use prior to 1976 (which EEG-nf was) were allowed to continue being sold. Although regulatory agencies only accept EEG-nf for very narrow purposes, practitioners attempt to treat a wide range of conditions.

In my (Ghaziri's) 5 years of coaching under the supervision of a neuropsychologist, we used neurofeedback to help patients suffering from ADHD, anxiety, autism spectrum disorder, depression, tinnitus (ringing in the ears), headaches, traumatic brain injury, and epilepsy; as well as for general cognitive enhancement in healthy individuals. Patients with ADHD, anxiety, and depression seemed to show the most improvement. Although it remains difficult to identify what exactly helped patients in this clinical setting (owing to the lack of a control group). A positive relationship between practitioner and patient, the general benefits of cognitive training, and high levels of motivation seemed to go a long way. For anxiety in particular, patients I saw seemed to use the feedback as a cue to focus on their breathing and remain mindful of their mental state. If they felt anxious and tense, the feedback would alter—but even then, the electrical activity from muscles, rather than directly from the brain, may have driven this change (see Chapter 7). In many cases the benefits I observed seemed to rest largely on the coaching framework, mainly by reassuring the patients and providing tips for how to relax, and less on viewing one's own brainwaves. Robust studies back up this point and find that EEG-nf seems to improve some conditions, but independently of the feedback patients receive [2].

The literature on other conditions, such as tinnitus and epilepsy, suggests that EEG-nf may work, but the findings often come from experiments with few participants (see Chapter 12), no control group, and a body of evidence that may suffer from publication bias that sways the evidence in favor of EEG-nf. Thus for some patients where no other treatment seems to work, EEG-nf offers some hope as a last resort regardless of how strong the base of evidence.

Instead of focusing on behavior, some EEG-nf practitioners seem more interested in normalizing brainwaves. In a method termed quantitative EEG, or simply qEEG, these practitioners often deem neurofeedback successful when, after training, the brainwaves of patients more closely match an average profile derived from a database of scans taken from healthy individuals. And yet, idolizing "normal" brainwave patterns is like arguing that people should all strive to be the same "optimal" height—even if that means stretching some people and squishing others. The

shape and size of the human brain and skull varies substantially between individuals. Even if two brains produced the same activity, the signal would look different by the time it reaches the EEG sensors placed on the scalp. Moreover, qEEG results are widely heterogeneous both between individuals and within single individuals at different time points. Numerous factors influence the qEEG including how you slept last night, whether you're having a good day, and if you drank coffee before the recording. When looking at the most comprehensive list of publications that specifically trained qEEG patterns, we find that 95% of the authors either practice this technique privately or sell the equipment to do so [3].

Rather than create "normal" brain activity, EEG-nf primarily aims to train positive behaviors that generalize into everyday life. In my own study, we found that EEG-nf alters the brain as measured by structural magnetic resonance imaging (MRI); however, we found poor behavioral differences between participants given genuine versus sham feedback [4]. While some EEG-nf advocates may argue that our study proves that EEG-nf entails measurable benefits above and beyond placebo effects, in terms of behavioral benefits it suggests the opposite, especially considering that the study does not meet the standard of clinical research (e.g., double-blind and sufficient sample size).

As neuroscientists, we must keep a critical eye on the literature. The lack of standard protocols is the weakest link of neurofeedback. Indeed, research reports rarely described the protocol used in full detail. Some clinicians seem to simply place their patients in front of a screen displaying neurofeedback for a half hour and hope that everything fixes itself. Other practitioners continuously interact with their patients throughout training. Some tailor the feedback to each patient. Others present standardized feedback. We imagine that regardless of why patients improve (via specific EEG-nf-related mechanisms or placebo effects), more interaction would help amplify positive treatment outcomes. Encouragement seems to help patients maintain a minimum level of effort that allows them to reap benefits. Hence, EEG-nf seems to be mostly a mindfulness training technique that would require a certain level of metacognition and self-regulation and uses neurotechnology to maximize participant motivation. In support of this point, meta-analyses show that deliberate practice, rather than other more general processes, accounts for only a small percentage of performance capacity across a number of domains such as playing video games (28%), learning a musical instrument (21%), and practicing a sport (18%) [5]).

This conclusion is worrisome when we consider the cost of EEG-nf and the population that seeks this treatment. They are often vulnerable, have exhausted many other treatment options, and decide to place their final hopes (and money) on up to 40 sessions of EEG-nf. With its current price tag, and the seeming equivalence between genuine and sham feedback, it should be practiced with some caution.

We do, however, maintain interest in the use of neurofeedback as a tool to control brain−computer interfaces (Chapter 4) and in research to better understand the relation between brain and behavior (Chapter 3). These fields come with a distinct

literature and separate set of evidence compared to that surrounding EEG-nf. We also remain hopeful that other advancements in neurofeedback, such as combining fMRI-nf with machine-learning algorithms [6], will develop into fruitful treatments.

In a word, EEG-nf has yet to reach the status of evidence-based medicine. Robust experiments show an equivalence between genuine and sham EEG-nf. Nonetheless, EEG-nf practitioners continue to forge ahead while shying away from discussing the glaring caveats.

Additional readings

A popular-style and critical blog post on EEG-nf written by a buster of brain myths: <https://www.psychologytoday.com/blog/brain-myths/201302/read-paying-100s-neurofeedback-therapy-0>.

A succinct academic letter that highlights the peculiar climate surrounding EEG-nf research and practice: Thibault RT, Lifshitz M, Raz A. The climate of neurofeedback: Scientific rigour and the perils of ideology. Brain 2018;141(2):e11. Available from: http://doi.org/10.1093/brain/awx330.

A thorough and historical review of the most common neurofeedback modalities: Thibault RT, Lifshitz M, Birbaumer N, Raz A. Neurofeedback, self-regulation, and brain imaging: clinical science and fad in the service of mental disorders. Psychother Psychosomat 2015;84(4):193−207. Available from: https://doi.org/10.1159/000371714.