

# **Supporting Meditative Awareness through Neurofeedback Wearables**

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# 1 Introduction

Adoption and functionality of wearable devices are increasing and expected to continue to do so [23]. In the west, meditation is accepted more widely as a means of health improvement [2]. Consumer EEG devices and freely available EEG/ERP databases [24] offer a chance to use algorithms to analyze a user's meditation experience and provide feedback for improvement. This work presents the current state of art of consumer EEG devices, the signals involved in meditation and the possibility for usage of such devices for meditation training. In the end, three popular EEG headsets will be compared and evaluated.

## 1.1 EEG

EEG stands for electroencephalography and is a process to record the electrical activity in the brain. The measured signal are voltage changes in and between neurons. EEG can only measure measure signal in the outer regions of the brain [29]. The brains signal is in the order of mikrovolt [9]. For measurement, EEG electrodes are placed on the test subjects scalp. In Research, up to 256 electrodes are used [10], while consumer grade devices use around 10% of this. [11] The electrical signal is measured as frequencies and go through an EEG amplifier. These get passed to a Fast Fourier Transformation (FTT) or wavelet transformation [13] to produce distinct waves, which are then categorized according to known patterns [14]. Brain waves of individuals can be compared to aggravated data of many test subjects, to search for disorders [19] or match for meditation success [2], access to enough datapoints assumed. There are four main brain frequencies [6]:

- Beta Waves (frequency range from 14 Hz to about 30 Hz), associated with intellectual activity and outwardly focused concentration
- Alpha Waves (frequency range from 7 Hz to 13 Hz), associated with relaxation
- Theta Waves (frequency range from 4 Hz to 7 Hz), associated with mental inefficiency [26], zone between wake and sleep
- Delta Waves (frequency range up to 4 Hz), associated with sleeping, learning disabilities [26]

From the data, conclusions about attention [17], stress [18], cognitive load [16] and more are possible. While EEG caps are usually used in research and academia [10], headsets provide a reasonable solution for consumers with less complexity, but also lower precision[11]. For the accuracy of the measurement it is still crucial, that the sensors are correctly affixed [10], so that they measure the brain regions that are involved in meditation.

EEG devices are either gel based or dry. In Research, gel electrodes are used and cost thousands of dollars, have wired signal transmission and are time consuming to setup and are uncomfortable to wear. Consumer devices on the other hand are dry, wireless and cost only a few hundreds of dollars. [21]

## 1.2 Neurofeedback

Neurofeedback (NFB), also called EEG biofeedback, is a therapy that was invented as a method for training brainwave patterns through operant conditioning and is known since the 1960s [26]. It is used not only as a treatment of disorders, but also in peak performance training. NFB experiments led to the development of the field of brain-machine interfaces [29]. Operant conditioning is the learning process where a behavior is modified by punishment or reward, the famous example being Pavlov's dog [28]. NFB never uses punishment though. In NFB, the neural activity is recorded and presented to the participant in real time. Usually people are not aware of their brain waves, so seeing them on a screen helps by giving you the ability to influence them. This is the operant conditioning part. In the beginning, the changes are only short-lived, but with practice can become lasting.

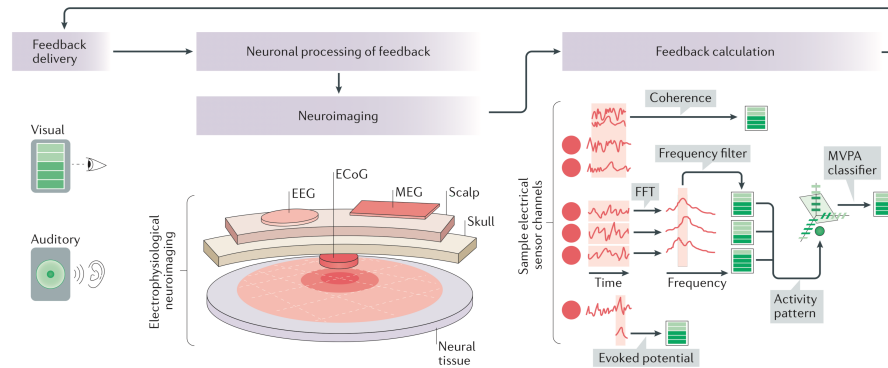


Fig. 1: The neurofeedback process

Source: Sitaram et al, 2016

NFB is non-invasive and is sometimes used as an alternative to medication [26]. Another unique kind of NFB is called LENS, where a tiny electromagnetic signal is introduced to the electrodes and transported to the brain. However, it is not recommended to use NFB equipment without any expertise. Also, the training should be individualised to the unique brainwave patterns of each person. A physician should always be consulted first. Otherwise, negative side effects or degradation of existing disorders are possible. Only healthy individuals should use a NFB device for meditation training on their own risk.

## 1.3 Meditation

Over the last decades, meditation has gained the interest of popular culture and the scientific community. Documented beneficial effects range from mood improvements to structural changes [20] in various regions of the brain, such

as the amygdala (responsible for stress and anxiety), anterior cingulate cortex, brain stem (breathing) and the default mode network [2]. Therefore, meditation has become part of psychiatric interventions [5], high performance sports and personal development. Historically, meditation stems from buddhist practices and has been part of eastern culture for centuries, though variations were also practiced by the ancient greeks [22].

Though there is not one single meditation practice, the methods are plentiful. While often associated with stillness and watching ones breath, there are also more active forms of meditation that involve more movement. Travis and Shear categorize meditation practices into focused attention, open monitoring and automatic self-transcending.[4] Since this categorization is based on different EEG patterns and would be part of the wearable device, I will follow this categorization and differentiate where appropriate.

All these potential benefits lead to an increasing populace that wants to learn and practice meditation, so that a device that helps in the acquisition of this skill becomes desirable. The demands, functions, challenges and applications for such a device are the topic of this work.

#### **1.4 Awareness**

Mindfulness and awareness are two terms often mentioned in the context of meditation and there is no exact, agreed upon scientific definition to separate these two.

## **2 Goals**

Since the beneficial effects of meditation are so various, the potential goals of using a wearable device that provides neurofeedback to its user are inherently diverse. Machine assisted meditation could help individuals to improve faster, track their progression, analyze the state of mind and lower the entrance barrier for novel practitioners. [1]

The differences in EEG signals induced by the different meditation practices enable a categorization and dedicated training regime to offer the device and software solution to a wider audience. [4]

## **3 Measurement Data**

### **3.1 Biological Signals**

- EEG
- brain blood flow infrared spectroscopy

Combination of NIRS and EEG would be optimal! There is no such device yet for consumers though. Possible?

### **3.2 Measuring**

### **3.3 Challenges**

Such a QEEG Assessment usually takes about 1.5 hours, which is too long for a consumer. Involuntary movement of the tongue, eyeballs, jaw and facial muscles produce noise in the milivolt range, while brain signals are on the order of mikrovolt. These artifacts do not only occur in consumer grade EEG devices, but also in medical grade. These artifacts need to be filtered out to produce a reliable signal for further analysis [3], which will be extremely difficult, since the device would need to know when a person moved even so slightly [26].

The time window of measurement is also crucial for the accuracy of machine learning models.

### **3.4 Processing and evaluation**

[15]

## **4 Training procedure**

## **5 Available Devices**

### **5.1 Neurosky - Mindwave Mobile 2**

### **5.2 InteraXon Inc. - Muse 2**

### **5.3 Emotiv - Epoc+**

## **6 Conclusion**

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