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A novel EEG for alpha brain state training, neurobiofeedback and behavior change

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A B S T R A C T

Mindfulness meditation, with the resulting alpha brain state, is gaining a strong following as an adjunct to health, so too is applying self-affirmation to stimulate behavior change through subconscious re-programming. Until recently the EEG technology needed to demonstrate this has been cumbersome and required specialist training. This paper reports a pilot study using a remote EEG headband, which through a sophisticated algorithm, provides a real-time EEG readout unencumbered by conventional artifacts. In a convenience sample of 13, the difference in brain waves was examined while the subjects were occupied in an 'attention' and an 'alpha mind state' exercise. There was a significant difference in the mean scores for theta, delta, beta and gamma brain waves. Alpha brain waves remained static suggesting an ability of the headset to discriminate a mindful state and to provide real-time, easy to interpret feedback for the facilitator and subject. The findings provide encouragement for research applications in health care activities providing neurobiofeedback to subjects involved in mindfulness behavior change activities.

1. Introduction

Since Hans Berger was able to demonstrate the alpha, or Berger's wave in the 1930s,[1] the machines and their output have remained largely in the hands of neurologists and expert technicians, using the technology for diagnosis and treatment of neurological disorders. Recent, rapid technological advancements and the widened ability to read and use the EEG, are seeing previously impossible applications looming as possibilities for clinicians both mental health and general, in private practice, in hospitals, clinics and the community. One appeal is the applicability of the technology across professions from medicine, nursing, physiotherapy, psychology to osteopath.

Combined with the concept that a relaxed mind (an alpha brain state) enhances learning as well as psychological and physical well-being, this novel opportunity to 'view' that state enhances the likelihood of sustainable behavior change. Treatment of anxiety, depression and sleep disorders by teaching deep relaxation techniques paired with mindfulness and auto-suggestion as well as giving instant EEG biofeedback, are now possible. These new advances in neuroscience are presenting opportunities for clinicians to expose clients to double biofeedback experiences. Not only can clients experience the positive emotional feedback of moving into an alpha brain state, they can also gain feedback from the real-time viewing of their own brain waves as they practice various meditation techniques: double barreled biofeedback!

This paper explores the possibilities for use of a novel EEG by clinicians and in helping people develop alpha brain states to enhance behavior change.

2. Literature review

In view of the rapid and future potential expansion of the applications of EEG technology to several branches of health care, education and human resources development, the literature review was conducted using the CINAHL and ERIC databases. Most of the relevant material was published after 2008.

2.1. The EEG

Electrical activity in the brain can be measured by electrodes placed on the skin. The five types of rhythm, or brain waves which are generated and reported in the literature are alpha, beta, gamma, delta and theta. Their number of waves per second, or Hertz characterizes their features on the classic EEG readout, and their appearance has been linked to certain regions and related activities within the brain (Table 1).

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Table 1
Comparison of activities and brain changes.

Study	Brain wave	Activity	Brain wave change
Kirenskaya et al., 2011	Alpha and theta activity	EEG spectral power in HH and LH HH subjects engaged in imagination, LH in linguistic activity	Coherence between theta and alpha band elevated in HH subjects; beta2 and gamma1 higher in LH; coherence between frontal and posterior areas in beta–gamma higher in HH
Antonenko et al., 2010	Alpha and theta	Cognitive Load on Working memory when learning new tasks	
Field et al., 2010	Increased theta activity	Yoga/tai chi, heart rate, relaxation, anxiety	Increased theta
Baghdadi and Nasrambuti, 2009	Delta and beta	Hypnotic suggestion	Decreased delta and beta
White et al., 2009		$N = 7$ HH–LH	Beta coherence in HH and increased in LH between medial, frontal and left prefrontal sites
Lagopoulos et al., 2009	Increased theta and alpha	Meditation: experienced meditators, resting and meditating	Increased theta in frontal and temporal-central; increased alpha in posterior; decreased delta in posterior; NS for beta
Belkofer and Konopka, 2008	Alpha, beta, delta	Art therapy compared to rest	Increased alpha and beta; decreased delta and theta
West, 1980			Increased alpha amplitude and frequency; rhythmic theta traits

Conventionally raw EEG data is obtained through several electrodes (up to 20) attached to strategic areas of the scalp, which are connected to a semi-portable machine. The readings are sensitive to movements such as eye blinking and breathing, so patients needed to be as still as possible. This 'qualitative' EEG requires lengthy, time-consuming analysis by experts in clinical conditions, and 12 methods and their specific purposes which have been developed in 'quantitative' analysis of the EEG.[2] These methods enhance the raw EEG by quantitatively compressing and extracting critical features. Despite the complexity involved in the development of these methods, they encourage the use of these methods where clinical care can be improved. Such is the rapidity of the development of Brain Computer Interfaces (BCI) that some can only speculate on their use beyond the conventional laboratory or restricted clinical settings.[2,3] BCIs are light, portable and user friendly devices for reading brain waves.

One more recent study commented on the explosion of research and application of BCI devices in a paper which examined usability from an ergonomic perspective.[4] It was noted that there were two commercially available devices, the *NeuroSky Mindwave* and the *Emotiv EPO*.

Remote technology combined with sophisticated computer algorithms has enabled BCIs to be used in real-time, rather than in artificial laboratories, and restricted clinical environments. A paper which seems to be the first of its kind,[5] reports a sophisticated algorithm that produces a non-expert friendly computer screen which can remotely visualize EEG rhythms. In their study the subjects wore a minimally invasive headset (a headband and ear piece) called the 'Neurosky Mindset Brain–Computer Interface' (NeuroSky, Inc.) (NMS), and performed real life tasks. The NMS was developed for leisure use but the makers claim that it has further, far reaching research and clinical applications.

The NMS headband contains three dry electrodes, two on the forehead and one on the ear piece. The neuronal activity is visualized on a remote computer which produces a figure containing two horizontal line graphs, one called 'attention', the other 'meditation', on a scale of 0–100. This provides a relative indication of the degree of meditation and attention, the range of which is from 0 to 40 (low), 41 to 60 (average), 61 to 80 (moderate) and 80 to 100 (high). At the same time another figure provides an active bar chart of delta, theta, low alpha, high alpha, low beta, high beta, low gamma and high gamma brain wave power band levels. The vertical axis ranges from 0 to 3000. At the conclusion of the session, two outputs are provided. The first is a screen which shows: 1. A pie chart of the percentage of time spent in the four ranges; 2. A dial which indicates the overall degree of meditation from weak to high; and 3. A complete graph of all brain waves for the session marked at 10-s intervals. The second output is a spreadsheet which contains raw data at one second intervals for meditation and attention scores and scores for each of the brain waves.

2.2. EEG and education

In a recent review of the EEG and its use in measuring cognitive load,[6] the authors were optimistic about the use of new EEG technology which shows alpha and theta brain waves for the measurement of cognitive load, which is the load imposed upon working memory when learning new tasks. Modern EEG readings with computerized filters can remove unwanted artifacts and provide measurements which are continuously reflective of a participant's cognitive status. For example in determining cognitive load when comparing students and different degrees of intelligence in which there are lowered event related de-synchronization (ERD) in alpha bands. The quantification of alpha brain wave changes can be calculated by the decrease or increase in activity event related synchronization (ERS) related to an event (an instructional manipulation) and compared to a baseline.

The Strop test for selective attention, cognitive flexibility and processing speed, and the Tower of Hanoi problem-solving test were applied to examine the effectiveness of the NSM.[5] The features of the sample of 20 were not stated. The authors concluded that the headset can be used as a monitor for emotional response in a test environment. While methodologically unclear, this paper does represent a landmark in that it is a very early report of the use of BCI's as real-time measure of cognitive and emotional brain waves.

2.3. EEG, meditation and hypnosis

The last decade has seen the growth of mindfulness meditation, and concurrent observation of changes in alpha and beta brain waves as a therapeutic tool for mental health practitioners when working with people with depression and anxiety disorders in particular, and in conjunction with techniques such as art therapy[7] tai chi, yoga[8] and positive affirmations. There is also an increasing body of literature demonstrating the effectiveness of these interventions for medical and psychological disorders such as sleep, pain and cancer.[9] So too hypnosis has benefitted from the EEG which has helped demonstrate differences in low (LH) and high hypnotizable (HH) subjects.

Some convincing recent literature using the EEG has demonstrated that meditation activates regions of the brain which are