JOURNAL OF APPLIED BIOANALYSIS, August. 2024, p. 85-88.
http://doi.org/ 10.53555/jab.v10i2.165 (ISSN 2405-710X)
Vol. 10, No. 2

OPEN ACCESS

RESEARCH ARTICLE

Temporal Dynamics Of Brainwave Entrainment: Unveiling The Rhythmic Secrets Of The Human Mind

Dr. Rekha Chandra Mani Mds[1*], Dr. Vivek Narayanan Mds[2], Dr. Vimala Haribabu Mds[3], Dr. Prem Blaisie Rajula Mds[4]

[1*]*Assistant Professor, Department of Conservative Dentistry, SRM Kattankulathur Dental College and Hospital, Chengalpattu, Tamil Nadu, India. Email: rekham@srmist.edu.in*
[2]*Dean, SRM Kattankulathur Dental College and Hospital, Chengalpattu, Tamil Nadu, India. Email: dean.dental.ktr@srmist.edu.in*
[3]*Principal and Professor, The Government Pudukottai Dental College and Hospital, Tamil Nadu, India. Email: vimalaortho@gmail.com*
[4]*Assistant Professor, Department of Periodontics, SRM Kattankulathur Dental College and Hospital, Chengalpattu, Tamil Nadu, India Email: premblam@srmist.edu.in*

Background: The novel concept of brainwave entrainment (BWE) has found valuable applications in patients with ADHD, chronic pain, sleep disorders, stress, anxiety, drug addiction etc. However, most existing studies on BWE highlight an increase in the relative power of the applied frequency (alpha/theta/delta) compared to baseline EEG readings, which does not demonstrate an actual entrainment effect. Researches, aiming at precisely synchronizing brainwave frequencies with specific frequencies delivered through sensory stimulation and establishment of time required for the same are important for translation of BWE to clinics.
Materials and Methods: This study was conducted among ten consenting participants. Initial resting state EEG was assessed in all participants followed by application of audiovisual stimulation using an entrainment device (David delight plus, Mind Alive Inc. Edmonton, Alberta, Canada). The entrainment frequencies include alpha (10 Hz), theta (5.5 Hz), and delta (1 Hz).
Results: In all participants, audiovisual stimulation resulted in occurrence of the corresponding frequency brainwaves in parietal and occipital cortices. The mean time required for occurrence was 1.39 minutes for alpha group, 2.27 minutes for theta group and 3.0 minutes for delta group.
Conclusion: Determining the frequency and timeframe of BWE are crucial for optimizing its application in clinical and therapeutic settings.

Keywords – *Brainwaves, brainwave entrainment, alpha, theta, delta*

Introduction

The exploration of brainwave entrainment (BWE) and neurofeedback techniques are at the forefront of neuroscientific research, offering promising avenues for non-invasive modulation of brain activity to influence various psychological and physiological states. These auditory phenomena, where the brain synchronizes its frequency with that of an external rhythm, has the potential to alter states of consciousness, manage pain, reduce anxiety and even enhance cognitive functions (1-3).

In the realm of clinical application, the management of acute pain and anxiety presents a significant challenge. Researchers have investigated the potential of auditory and visual stimuli, specifically oscillating within the alpha frequency range (8-12 Hz), to modulate these conditions (4). The alpha band, traditionally linked with relaxed yet alert states, is hypothesized to play a pivotal role in the perception and modulation of pain and anxiety (4,5). By entraining brainwaves to specific frequencies within this band, researchers aim to elucidate the potential of BWE as a non-

***Corresponding Author:** Dr. Rekha Chandra Mani MDS Assistant Professor, SRM Kattankulathur Dental College and Hospital, SRM University, KTR campus, Potheri, Kattankulathur, Tamilnadu 603203. Mobile no: 9444810543 Email: rekham@srmist.edu.in Orcid ID: 0000-0003-4164-4833*

pharmacological intervention for pain and anxiety, commonly encountered in various clinical settings.
Despite the promising applications, the field is characterized by methodological diversity and inconsistency in outcomes. (6) . Furthermore, the review highlights the need for research with regards to timing, duration and frequency of the stimulation to determine the clinical application for maximum efficacy-4 (6).

Schwarz and Taylor (2005) demonstrated that alpha auditory stimulation enhances the relative alpha power (8-12Hz) compared to the baseline electroencephalogram (EEG) (7). Additionally, studies by Spaak et al. (2014) on combined visual and auditory alpha entrainment revealed immediate enhancements in relative cortical alpha power against baseline EEG readings (1). Xiang Gao et al. (2014) explored the effects of five-minute binaural beats entrainment across four frequencies: delta band (1Hz), theta band (5Hz), alpha band (10Hz), and beta band (20Hz), uncovering an increase in relative power (RP) within the applied frequency range compared to a baseline EEG (8). In a more recent study, Hamza Abubakar Hamza (2023) focused on 10Hz binaural beat frequencies, yielding a frequency range of 6-13Hz in the EEG (9).

The prevailing trend in contemporary research highlights an increase in the relative power of the applied frequency (alpha/theta/delta) compared to baseline EEG readings, without demonstrating actual brainwave entrainment effects. Current research should aim at precisely synchronizing brainwave frequencies with specific frequencies delivered through sensory stimulation (whether auditory, visual, audiovisual, or tactile). According to a systematic review and meta-analysis by Maddison R et al., transitioning brainwave entrainment (BWE) from research to clinical settings requires identification of the specific frequency of stimulation that elicits an effect and determination of the duration necessary for entrainment to that frequency (6). Despite the promising applications, the field is characterized by methodological diversity and inconsistency in outcomes. The systematic review further addresses this issue by evaluating the current state of research, advocating for methodological rigor and standardization in future studies Therefore, the primary goal of this study is to ascertain the feasibility of synchronizing brainwaves, in the parietal and occipital cortices, to the precise frequency administered via audio-visual stimulation, with a secondary objective of estimating the time required for this synchronization.

Materials and Methods

This Pilot study was approved by Institutional Ethics Committee of SRM Kattankulathur Medical College and Hospital. The device used for audiovisual entrainment consisted of a Tru-Vu Omniscreen Multi-Color Eyeset and a headset with five inbuilt sessions of different frequencies. (David Delight plus audiovisual device for entrainment, manufactured by Mind Alive Inc. Edmonton, Alberta, Canada). Turning on a session produces the corresponding frequency to be played in the headset while feeble light-emitting diode (LED) lights blink in synchronizing with the headset frequency.

Ten ASA-I volunteers, in the age group of 18- 30 years, participated in the EEG (RMS EEG superspec v4.2.49, Haryana, India) analysis. People with history of epilepsy, head injury, psychiatric illness, systemic diseases, currently using any drugs or alcohol and pregnant women were excluded from the study. In accordance to IFSECN, the 10-20 electrode placement system was followed. For all participants base-line EEG recordings was done for 3 minutes followed by entrainment with alpha (10Hz), theta(5.5Hz) and delta (0.5-1Hz) frequencies. Therefore, a total of 30 entrainment sessions and 30 baseline sessions were applied. In between frequency switching, the entrainment device was turned off for 3 minutes to make sure the participants return back to the baseline frequency before the next frequency was applied. After an initial baseline session of 3 minutes, application of the first frequency was performed. The time interval between the beginning of application of the 1st frequency and synchronization of parietal and occipital cortices to the exact applied frequency was recorded. This was followed by the application of baseline frequency for 3 minutes again and then beginning of second frequency application and so on. Descriptive statistical mean values were calculated.

Results

Results showed that the mean time required for entrainment with alpha (10Hz) frequency was 1.39 minutes, 2.27 minutes for theta (5.5Hz) and 3.0 minutes for Delta (1Hz) frequencies. The mean time required for Delta entrainment was maximum followed by theta and alpha frequencies.

S.No	Participant Number	Time for alpha entrainment (min)	Time for theta entrainment (min)	Time for delta entrainment (min)
1.	P1	0.47	1.66	4.28
2.	P2	1.64	3.75	5.58
3.	P3	2.49	2.04	1.6

4.	P4	1.87	2.12	2.1
5.	P5	0.49	1.92	0.84
6.	P6	1.88	1.2	3.36
7.	P7	2.21	2.12	2.85
8.	P8	1.0	2.0	5.5
9.	P9	1.05	2.82	1.22
10	P10	0.84	3.14	2.1
	Mean	1.39	2.27	3.0

Discussion

Entrainment works by transcending the existing brainwaves to lower frequencies which are more relaxing in nature, thereby reducing anxiety. In contrast to other audiovisual devices which work by psychological distraction methods, entrainment works physiologically by transcending the brainwaves to desired state. For this reason, BWE is particularly effective in management of mental afflictions as in case of drug-addiction, depression, anxiety, sleep disorders, pain control, etc. BWE has also been employed for improvement of mental skills so as to increase focus, concentration, attention deficit hyperactivity disorder (ADHD), creativity, etc.(10)

Studies have shown that neural entrainment with alpha frequencies by visual and auditory stimulation methods was effective in reducing acute pain. In particular, visual or auditory entrainment at 8, 10 or 12 Hz resulted in lower pain intensity ratings for acute pain induced by laser stimulation or during surgery relative to a control sensory stimulation.(4,11)These results complement EEG studies which found a reduction of alpha power during painful stimulation (12-15). Interestingly, Ecsy et al. found that the 10 Hz visual entrainment was shown to result in a reduction of the P2 peak amplitude, which may reflect cortical responses to nociception (4).

Audiovisual entrainment with alpha range has been shown to produce an immediate increase in the brainwaves oscillating in the alpha frequency throughout the cortex (1,16). The other regions of brain also tend to fall into a lock step with the stimulated cortex resulting in entrainment(1,17-20).

There was no consistent evidence that BWE reduced pain intensity for chronic pain (21). By comparison, auditory theta entrainment was shown to be effective in reducing chronic pain (22,23). The results from these studies are surprising as chronic pain has been characterized by an increase in theta power due to altered thalamo-cortical activity (24,25).

In this study, the 10-20 electrode placement system was followed and this is in accordance to the recommendation by International Federation of Clinical Neurophysiology (IFSECN). Given that visual stimulations are processed in the occipital cortex and auditory stimulations in the parietal cortex, entrainment times were determined by examining the synchronization of occipital and parietal electrodes. In order to rule out bias, after entrainment to each frequency, entrainment was stopped for 3 minutes to restore back to the resting baseline EEG before the next frequency was applied. A total of 30 entrainment sessions and 30 baseline sessions were applied. The mean time required for entrainment with alpha (10Hz) frequency was 1.39 minutes, 2.27 minutes for theta (5.5Hz) and 3.0 minutes for Delta (1Hz) frequencies. This is expected as alpha range is closer to the baseline EEG frequency compared to theta and delta frequency ranges. To the best of authors' knowledge, this study is the first of its kind to establish actual entrainment effect, with alpha, theta and delta frequencies, in the parietal and occipital cortices. Previous study by Xiang Gao et al. (2014) using five-minute binaural beats entrainment across delta band (1Hz), theta band (5Hz), alpha band (10Hz), and beta band (20Hz), revealed an increase in relative power (RP) within the applied frequency range compared to a baseline EEG which does not demonstrate an actual BWE effect. Although BWE has found numerous applications in clinical medicine, data available on the stimulation duration for entrainment is still scanty. This study is also the first of its kind to precisely establish the minimum duration required for audiovisual entrainment using EEG.

Limitations and Future perspectives and Conclusion

One of the main drawbacks of this study was the sample size. More studies with larger sample sizes and double-blinded randomisation would also be necessary before implementation into clinical settings. There exists necessity for continued research to unravel the complexities of BWE ensuring effective and scientifically validated application in therapeutic settings.

References

1. Spaak E, de Lange FP, Jensen O. Local entrainment of α oscillations by visual stimuli causes cyclic modulation of perception. J Neurosci 2014;34(10):3536–3544. DOI: 10.1523/JNEUROSCI.4385-13.2014

2. Locke HN, Brooks J, Arendsen LJ, et al. Acceptability and usability of smartphone-based brainwave entrainment technology used by individuals with chronic pain in a home setting. Br J Pain 2020;14(3):161–170. DOI: 10.1177/2049463720908798
3. Manippa V, Palmisano A, Filardi M, et al. An update on the use of gamma (multi) sensory stimulation for Alzheimer's disease treatment. Front Aging Neurosci 2022;14:1095081. DOI: 10.3389/fnagi.2022.1095081
4. Ecsy K, Jones AK, Brown CA. Alpha-range visual and auditory stimulation reduces the perception of pain. Eur J Pain 2017;21(3):562–572. DOI: 10.1002/ejp.960
5. Pino O. A randomized controlled trial (RCT) to explore the effect of audio-visual entrainment among psychological disorders. Acta Biomed. 2022;92:e2021408. doi: 10.23750/abm.v92i6.12089.
6. Maddison R, Nazar H, Obara I, Vuong QC. The efficacy of sensory neural entrainment on acute and chronic pain: A systematic review and meta-analysis. British Journal of Pain. 2022 Nov 10:20494637221139472.
7. Schwarz DW, Taylor PJ. Human auditory steady state responses to binaural and monaural beats. Clinical Neurophysiology. 2005 Mar 1;116(3):658-68.
8. Gao X, Cao H, Ming D, Qi H, Wang X, Wang X, Chen R, Zhou P. Analysis of EEG activity in response to binaural beats with different frequencies. International Journal of Psychophysiology. 2014 Dec 1;94(3):399-406.
9. Hamza HA, Hassan AR, Mohammed U, Sharpson MI. Binaural Beat Effect on Brainwaves, Stress Management and Its Applications. African Journal of Advances in Science and Technology Research. 2023 Dec 31;13(1):21-9.
10. . Honores, Marcelo. (2016). What is Brainwave Entrainment and what is it for? Febrauary 2016.
11. Olcucu MT, Yilmaz K, Karamik K, et al. Effects of listening to binaural beats on anxiety levels and pain scores in male patients undergoing cystoscopy and ureteral stent removal: a randomized placebo-controlled trial. J Endourol 2021; 35: 54–61.
12. Shao S, Shen K, Yu K, et al. Frequency-domain EEG source analysis for acute tonic cold pain perception. Clin Neurophysiol 2012; 123: 2042–2049.
13. Peng W, Hu L, Zhang Z, et al. Changes of spontaneous oscillatory activity to tonic heat pain. PLoS One 2014; 9: e91052.
14. May ES, Butz M, Kahlbrock N, et al. Pre- and poststimulus alpha activity shows differential modulation with spatial attention during the processing of pain. Neuroimage 2012; 62: 1965–1974.
15. Hu L, Peng W, Valentini E, et al. Functional features of nociceptive-induced suppression of alpha band electroencephalographic oscillations. J Pain 2013; 14: 89–99.
16. Timmermann DL, Lubar JF, Rasey HW, et al. Effects of 20-min audiovisual stimulation (AVS) at dominant alpha frequency and twice dominant alpha frequency on the cortical EEG. Int J Psychophysiol 1999;32(1):55–61. DOI: 10.1016/s0167-8760(98)00064-6.
17. Dabiri R, Monazzam Esmaielpour MR, Salmani Nodoushan M, et al. The effect of auditory stimulation using delta binaural beat for a better sleep and post-sleep mood: a pilot study. Digit Health 2022;8:20552076221102243. DOI: 10.1177/20552076221102243
18. Opartpunyasarn P, Vichitvejpaisal P, Oer-Areemitr N. The effect of binaural beat audio on anxiety in patients undergoing fiberoptic bronchoscopy: a prospective randomized controlled trial. Medicine (Baltimore) 2022;101(24):e29392. DOI: 10.1097/MD.0000000000029392
19. Huang TL, Charyton C. A comprehensive review of the psychological effects of brainwave entrainment. Altern Ther Health Med 2008;14(5):38–50. PMID: 18780583.
20. de Graaf TA, Gross J, Paterson G, et al. Alpha-band rhythms in visual task performance: phase-locking by rhythmic sensory stimulation. PloS one 2013;8(3):e60035. DOI: 10.1371/journal.pone.0060035
21. Arendsen LJ, Henshaw J, Brown CA, et al. Entraining alpha activity using visual stimulation in patients with chronic musculoskeletal pain: a feasibility study. Front Neurosci 2020; 14: 828.
22. Richardson WS, Wilson MC, Nishikawa J, et al. The well-built clinical question: a key to evidence-based decisions. ACP J Club 1995; 123: A12–A13.
23. Gkolias V, Amaniti A, Triantafyllou A, et al. Reduced pain and analgesic use after acoustic binaural beats therapy in chronic pain: a double-blind randomized control cross-over trial. Eur J Pain 2020; 24: 1716–1729.
24. Sarnthein J, Stern J, Aufenberg C, et al. Increased EEG power and slowed dominant frequency in patients with neurogenic pain. Brain 2006; 129: 55–64.
25. Llin´as RR, Ribary U, Jeanmonod D, et al. Thalamocortical dysrhythmia: a neurological and neuropsychiatric syndrome characterized by magnetoencephalography. Pro Nat Acad Sci 1999; 96:15222–15227.