Acoustic and Biomedical Engineering

Influence of Infrasound on the Alpha Rhythm of EEG Signal

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The alpha waves were first registered and named by Berger in 1929. They are oscillations in the frequency range 8–12 Hz, originating from the occipital lobe during wakeful relaxation with closed eyes. The alpha blockage is the result of desynchronisation of the bioelectric activity of the brain induced by sensory stimulation. When the subject's eyes are closed, the alpha rhythm is generated. As soon as the eyes are open, alpha disappears. This is called alpha block and may be elicited also by any form of sensory stimulation. This replacement of the alpha rhythm is also called desynchronization because it represents a change of the synchronized activity of neural elements. This state is also called arousal or alerting response. Infrasounds are acoustic waves of frequency below 20 Hz. They are not directly perceived by humans because the natural frequency of vibrations of the part of the basilar membrane distant from the round window is about 20 Hz. The hearing organ, therefore, is well adapted to receive waves with frequency in excess of 20 Hz. The purpose of the experiment was to determine the effects of infrasound waves on variations in the alpha waves. Tests were done on a group of 32 participants. The experiment showed that infrasounds of frequency $f = 7$ Hz and acoustic pressure level SPL = 120 dB (HP) cause a statistically significant reduction of the alpha rhythm power.

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1. Introduction

Infrasounds are acoustic waves of frequency below 20 Hz. They do not cause any aural sensations and yet are received by the human body via a specific hearing tract (mainly through the hearing organ). The audibility depends on the acoustic pressure. Apart from the specific hearing tract, infrasounds are received by the vibration-sensing receptors, the threshold of perception being 20–30 dB more than the threshold of hearing.

The main sources of infrasound noise at work include turbo-machines (compressors, fans, motors), power machines and installations (grinders, boilers, funnels), metallurgical furnaces (electric arc furnaces), foundry machines (moulding machines, knockout grids), transport systems and wind power stations. Infrasound noise is also present in offices (ventilation and air-conditioning systems, lifts, IT network systems, and noise of the traffic outside).

The effects of infrasound noise on the human body have been recognised to a certain extent. Experimental data reveal variations in the circulatory systems, variations of bioelectric activity of the human brain during the infrasound exposure and changes in the level of activation [1–3].

The alpha waves were first registered and named by Berger in 1929. They involve rhythmic activity of the cerebral cortex in the frequency range 8–12 Hz. The occurrence of the alpha rhythm is attributed to the wakeful relaxation with the eyes closed. Alpha waves, best manifested in the occipital region in humans remaining with their eyes closed, have a variable amplitude, about 50 mV on the average. They evidence the synchronisation of activities of numerous dendrite units and appear during wakeful relaxation. The frequency of alpha waves changes but slightly, starting from early childhood right through to the age of maturity.

The alpha blockage is the result of desynchronised bioelectric activity of the brain and is induced by sensory stimulation. Eye opening causes the blocking reaction: decreasing or reduction of the alpha rhythm. Alpha waves tend to disappear during mental effort, when doing mathematical problems, when a person opens their eyes and responds to the light. The alpha blockage is the effect of desynchronised activity of neurons caused by mental concentration or stimulation of the sense organs. A rhythm in the alpha frequency registered in the vicinity of the motor cortex is also referred to as the *mu* rhythm (μ). It tends to disappear with movement or with the intention to move.

The alpha rhythm is replaced by fast low-amplitude wave forms, or beta rhythm. (When eyes are opened in a dark room, alpha blocking does not generally occur.) The degree and localization of blocking or desynchronization is associated with stimulus intensity, complexity, novelty, and meaningfulness [4]. Topographic analysis reveals whether EEG desynchronization is nonspecific (many or all sites) or selective (few sites). Nonspecific arousal is modulated by drugs, drowsiness, drive, and time of day, whereas sensory and strategic demands activate specific brain areas such as parietal and occipital cortex to visual stimulation and temporal cortex to acoustic stimulation [5, 6].

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The purpose of the experiment is to determine the effects of infrasound exposure of frequency $f = 7$ Hz and the sound pressure level SPL = 120 dB on the alpha rhythm power and to verify the alpha blockage hypothesis.

2. Methodology of research

The experiment was conducted on a sample of 33 subjects (male and female). The examined individuals were volunteers, who declared that they had not any medical conditions and were not under the influence of medicines. They had been also informed that before the experiment, they were not allowed to drink any stimulating nor intoxicating drinks. In the research, there were used infrasound with frequency $f = 7$ Hz and acoustic pressure level SPL = 120 dB (HP). The total duration of the experiment was 35 min. The exposition of the stimulus was 20 min. The acoustic signal, recorded in a wave format, was played from a computer.

The EEG test was about a registration (with a help of electrodes placed on the skin of a head) of functional currents of a human brain, whose characteristic feature is small tension (from several to several hundred microvolts). The frequency of these currents ranges from 0.5 Hz to 50 Hz. The registration of EEG signal was conducted with a help of 25-channel sound box of SAM 25 type of MICROMED company. EEG cap was fitted in accordance with a standard 10/20 system, where electrodes are placed along the sagittal line of the head (5 on the left side: Fp1, F3, C3, P3, O1 and 5 on the right side: Fp2, F4, C4, P4, O2 and a reference electrode on the OP, Pz).

The examined individuals were informed about the general target of the research, rules of the experiment and signed a permission form confirming their conscious agreement for the experiment. Later, after having cleaned the skin, measurement electrodes of EEG signals were fitted. After checking the effective resistance (proper applying of the electrodes), a tested person was comfortably seated on a testing site.

After conducting preparation activities, a proper experiment took place; that is 35 min of constant acquisition of EEG human bioelectric signals. The initial 5 min was without the infrasound exposition, 20 min with the signal exposition and 10 min — without the exposition [7, 8].

3. Result analysis

The obtained EEG runs were checked regarding the correctness of recording. The extreme values are excluded from further analyses. The mean amplitude of the alpha rhythm power (in the frequency range 8–12 Hz) is obtained in three time intervals: before, during and after the infrasound exposure and for each of the 10 channels separately. For each participants we get 30 observations of the mean alpha rhythm power (10 EEG channels, 3 stages of the test: stage 1 (prior to infrasound exposure), stage 2 (infrasound exposure), stage 3 (following infrasound exposure). The graphs of the signal power (μV^2) are shown in Fig. 1, in the three analysed time intervals (prior to, during and after the infrasound exposure) for one participant.

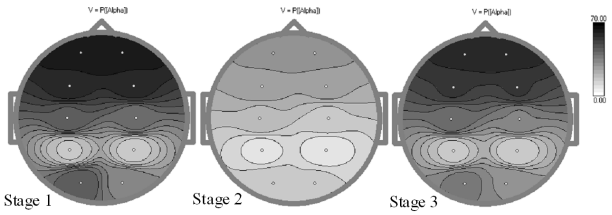

Fig. 1. Variations of the alpha rhythm power (μV^2) for the selected person. Stage 1 — prior to infrasound exposure. Stage 2 — infrasound exposure. Stage 3 — after the infrasound exposure.

The qualitative analysis reveals the reduction of the alpha rhythm power during the infrasound exposure for all test participants. Further, the alpha rhythm power tends to increase when the infrasound exposure is over.

As the analysed variables (the mean alpha rhythm power data) are not normally distributed, further analyses use a non-parametric Wilcoxon paired difference test, which takes into account the sign of differences, their magnitude and order. Once the differences are arranged in an increasing series, they are assigned a mean rank. Then ranks of negative and positive differences are added up separately. The smaller of the two sums becomes the Wilcoxon test value which is compared with the theoretical value given in Tables I and II to determine whether the null hypothesis should be accepted or rejected.

The statistical analysis of the test population reveals a statistically significant variation of the alpha rhythm power during the infrasound exposure (between stage 1 and 2). No statistically significant differences are found between stage 1 and 3 and between stage 2 and 3. Table I summarises the differences in significance levels between particular stages of the experiment for individual EEG channels (stage 1–2), (stage 1–3). (stage 1–3) denotes comparable time intervals, C — measurement channel in EEG; N — sample size, Z — the Wilcoxon test statistics, p — significance level for the Wilcoxon test, Fp1 to O2 — analysed EEG channels.

The results implicate a statistically significant difference of the alpha rhythm power during the infrasound exposure in relation to the conditions when no exposure is applied. No statistically significant differences are found between the stage 1 of the experiment (prior to infrasound exposure) and stage 3 (after the infrasound exposure). Even though no statistically significant differences are found between stage 2 and stage 3 (during the infrasound exposure and afterwards), the graphs of the mean alpha rhythm power reveal an increase of the alpha rhythm to the initial values (Fig. 2).

TABLE I

Significance of differences of alpha rhythm power between particular stages of the experiment. Wilcoxon test statistics (* — statistical significance $p < 0.05$).

	Stage 1–2			Stage 1–3			Stage 2–3		
C	N	Z	p	N	Z	p	N	Z	p
Fp1	31	3.13	0.0017*	32	1.30	0.1905	31	1.74	0.0811
Fp2	32	3.02	0.0024*	31	1.43	0.1525	31	1.27	0.2027
F3	32	3.25	0.0011*	32	1.42	0.1552	31	1.75	0.0794
F4	31	2.88	0.0039*	32	1.29	0.1969	31	1.37	0.1701
C3	32	3.19	0.0013*	32	1.49	0.1346	31	1.58	0.1124
C4	32	3.15	0.0016*	32	1.49	0.1346	31	1.76	0.0777
P3	32	3.02	0.0024*	32	1.72	0.0853	31	1.35	0.1763
P4	32	2.76	0.0056*	32	1.21	0.2242	30	1.32	0.1846
O1	30	2.54	0.0110*	31	2.27	0.0230*	30	0.23	0.8130
O2	31	2.09	0.0360*	31	0.58	0.5566	30	0.58	0.5577

TABLE II

Significance of differences of alpha frequency band power as a percentage of total power between particular stages of the experiment. Wilcoxon test statistics (* — statistical significance $p < 0.05$).

	Stage 1–2			Stage 1–3			Stage 2–3		
C	N	Z	p	N	Z	p	N	Z	p
Fp1	32	2.97	0.0029*	32	1.10	0.2699	31	2.57	0.0103*
Fp2	32	2.99	0.0028*	32	0.74	0.4601	31	2.21	0.0268*
F3	32	3.27	0.0011*	32	1.37	0.1722	29	2.30	0.0213*
F4	32	3.22	0.0013*	32	1.44	0.1499	31	1.78	0.0745
C3	32	3.40	0.0007*	32	1.55	0.1207	31	2.12	0.0343*
C4	32	3.46	0.0005*	31	1.80	0.0714	31	1.90	0.0573
P3	32	3.80	0.0001*	32	2.69	0.0071*	31	1.97	0.0489*
P4	32	3.52	0.0004*	32	1.66	0.0961	30	2.77	0.0057*
O1	32	3.16	0.0016*	32	2.26	0.0237*	31	2.41	0.0159*
O2	32	3.05	0.0023*	31	1.27	0.2027	31	2.55	0.0108*

The next step was compared of differences alpha frequency band power as a percentage of total power. Analyses were carried out between successive stages of the experiment.

The results implicate a statistically significant difference of the alpha frequency band power as a percentage of total power during the infrasound exposure in relation to the conditions when no exposure is applied. Statistically significant differences are found between the stage 2 of the experiment (during infrasound exposure) and stage 3 (after the infrasound exposure).

Table II summarises the differences in significance levels between particular stages of the experiment for individual EEG channels (stage 1-2), (Stage 1-3), (Stage 2-3) denotes comparable time intervals C — measurement channel in EEG; N — sample size, Z — Wilcoxon test statistics, p — significance level for the Wilcoxon test, Fp1 to O2 — analysed EEG channels.

The experiments reveal the occurrence of the alpha blockage during the exposure to infrasound with the frequency $f = 7$ Hz and acoustic pressure level SPL = 120 dB (HP). Statistically significant reduction of the alpha rhythm power is registered during the infrasound stimulation. The qualitative analysis reveals the increase of the alpha rhythm power after the infrasound exposure.

4. Conclusions

The alpha blockage is a well-known effect caused by desynchronised bioelectrical activity of the brain under the sensory stimulation. This phenomenon is registered even though the stimulus applied is the acoustic stimulus, not perceived directly by the aural system. Reduction of the alpha rhythm during the infrasound exposure is found on the statistical significance level $p < 0.05$. The increase of the alpha rhythm after the infrasound exposure is registered, though found to be statistically insignificant. No

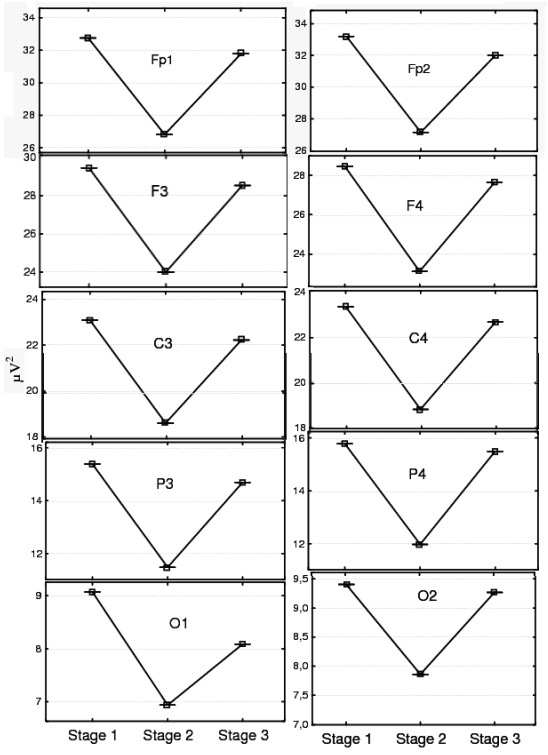

Fig. 2. Variations of the alpha rhythm power (μV^2) for 10 measurement channels (Fp1, F3, C3, P3, O1, Fp2, F4, C4, P4, O2) in particular stages of the experiment. Stage 1 — prior to infrasound exposure. Stage 2 — infrasound exposure. Stage 3 — after the infrasound exposure. Designations used: $\bar{}$ the mean and T the mean ± 0.95 of the confidence interval.

statistically significant differences are found between the alpha rhythm power prior to and after the infrasound exposure.

The results implicate a statistically significant difference of the alpha frequency band power as a percentage of total power during the infrasound exposure in relation to the conditions when no exposure is applied. Reduction of the alpha rhythm as a percentage of total power during the infrasound exposure is found on the statistical significance level $p < 0.05$. Statistically significant differences are found between the stage 2 of the experiment (during infrasound exposure) and stage 3 (after the infrasound exposure).

Acknowledgments

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