THE EFFECTS OF LOW FREQUENCY SOUND ON THE LEVELS OF ACTIVATION

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The paper summarises the research data showing how low frequency sound affects the level of activation in humans. Activation levels were measured with the use of the self-assessment questionnaire, known as the Activation-Deactivation Adjective Check List (AD ACL). The research program involved three independent stages and three types of acoustic stimuli were applied. The acoustic stimulus applied in the first stage had frequency $f = 7 \text{ Hz}$, sound pressure level $SPL = 120 \text{ dB (HP)}$. In the second stage participants were exposed to an acoustic stimulus $f = 18 \text{ Hz}$, sound pressure level $SPL = 120 \text{ dB (HP)}$. In the third stage a acoustic stimulus was applied $f = 40 \text{ Hz}$, sound pressure level $SPL = 110 \text{ dB (HP)}$. The exposure time in each experiment was constant (20 min). Results indicate a statistically significant increase of the deactivation – sleep effect following the low-frequency sound exposure.

Keywords: infrasound, low frequency sound, Thayer test, activation.

1. Introduction

The term “activation” is associated with physiological conditions of stimulation and energy release processes in the human body, aimed to get the organism ready to start a given activity. Underlying the theory activation is the fundamental hypothesis that distinguishes two independent aspects of human behaviour: direction and intensity. Activation is associated with intensity and its main function is to prepare the human body to start an external action. Broadly speaking, activation is understood as the body condition controlled by subjective and situational factors and described by a single-dimensional continuum.

The influence of the low-frequency sound on the levels of activation was investigated using the Thayer test (The Activation-Deactivation Adjective Check List AD ACL), developed on the basis of participants’ self-assessed, subjective feeling of well-being. A major advantage of the Thayer test lies in its approach to measurement of activation.
levels. Thayer was among the first researchers who appreciated self-assessment as an important technique to study the overall level of activation.

Accordingly, Thayer distinguished four basic dimensions (scales) of activation:

- General Activation;
- Deactivation – Sleep;
- High Activation;
- General Deactivation.

General Activation and Deactivation-Sleep scales are associated with excitation due to energy release, identified by the author of the test. High Activation and General Deactivation scales correspond to excitation from tension. Each dimension encompasses five adjectives describing the person’s subjective feeling of well-being.

The level of activation is indicated by a number of scored points. Tests conducted by Thayer and other researchers led them to the following conclusions:

- General Activation scale measures readiness to work, the result well predicts the effectiveness of cognitive actions;
- Deactivation – Sleep scale measures tiredness though daily variations of the test data might be the consequence of varied sleepiness effect;
- High Activation scale is a measure of tension and anxiety;
- General Deactivation scale provides information about the adaptive processes (when the body adapts itself to the applied stimuli), measuring the response to external or internal stimulation [4, 8].

2. Experiments

Experimental tests were performed in the Laboratory of Structural Acoustics and Biomedical Engineering at the Faculty of Mechanical Engineering and Robotics AGH-UST. The experimental program involved 96 tests, in three independent test conditions. Those taking part in the tests were 33 healthy persons (9 females and 24 males) aged 20–30 years. The experiment involved a threefold exposure to low frequency acoustic stimulus with the following parameters:

\[ f = 7 \text{ Hz}, \text{SPL} = 120 \text{ dB}, \]
\[ f = 16 \text{ Hz}, \text{SPL} = 120 \text{ dB}, \]
\[ f = 40 \text{ Hz}, \text{SPL} = 110 \text{ dB}. \]

The parameters of the applied stimuli were adapted in accordance with the pertinent standards and available literature on the subject of infrasound exposure [1, 5–7], an assumption was made that the exposure must be safe and must not be perceived as annoying. The effects of low frequency sound exposure on the selected human biopotentials (EEG, ECG, and EDA) were explored [2]. Those taking in the test part were categorized into groups depending on the Eysenck and Zuckerman test results.

Participants qualified for the experimental program did not report any prior ear disease or other chronic illnesses in their medical history.
The experimental procedure:
1. Thayer test.
2. A participant remained inside a pressure cabin – no stimulus for 5 minutes.
3. In the fifth minute the 20 min low frequency noise exposure began.
4. In the 25-th minute the exposure was over.
5. For the next 10 minutes the participant remained inside a cabin – no low frequency sound exposure.
6. Thayer test is repeated after those 35 minutes.

Acoustic signals were generated from the WAV file, using a computer. These signals are amplified in a power amplifier ELMUZ 2158 M and fed to the six speakers GDN 30/80 mounted in the cabin roof. The pressure (infrasonic) cabin is a rectangular prism, made from aluminium, with a self-supporting frame and lateral reinforcements. The main purpose was to raise the sound pressure levels through restricting the control volume and to isolate the participant from the external conditions in the laboratory. There were amplifiers installed in the cabin roof. In order to minimise the impacts of electromagnetic fields each cabin is secured with the Faraday’s cage on the inside. Each experiment involved 20 min exposure to low frequency sound.

3. Analysis

Thayer test data were treated statistically. Table 1 shows the descriptive statistics of the four scales, providing the mean value, 95% level of confidence and error before and after the low frequency sound exposure. Results are tabulated for the three test conditions: $f = 7 \text{ Hz}$; $\text{SPL} = 120 \text{ dB (HP)}$, $f = 18 \text{ Hz}$, $\text{SPL} = 120 \text{ dB (HP)}$, $f = 40 \text{ Hz}$, $\text{SPL} = 110 \text{ dB (HP)}$.

<table>
<thead>
<tr>
<th>Hz</th>
<th>N</th>
<th>Mean before</th>
<th>Mean after</th>
<th>Std. error before</th>
<th>Std. error after</th>
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<tbody>
<tr>
<td>7</td>
<td>General Activation</td>
<td>33</td>
<td>13.000</td>
<td>12.091</td>
<td>0.515</td>
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<td>High Activation</td>
<td>33</td>
<td>8.788</td>
<td>8.242</td>
<td>0.520</td>
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<td>Deactivation – Sleep</td>
<td>33</td>
<td>10.667</td>
<td>11.727</td>
<td>0.412</td>
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<tr>
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<td>General Deactivation</td>
<td>33</td>
<td>14.697</td>
<td>15.121</td>
<td>0.453</td>
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<td>18</td>
<td>General Activation</td>
<td>32</td>
<td>12.750</td>
<td>12.313</td>
<td>0.512</td>
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<td>7.969</td>
<td>8.219</td>
<td>0.499</td>
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<td>10.969</td>
<td>11.656</td>
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<td>15.250</td>
<td>15.375</td>
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<td>40</td>
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<td>12.968</td>
<td>12.129</td>
<td>0.623</td>
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<td>8.129</td>
<td>8.774</td>
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<td>12.000</td>
<td>0.505</td>
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<td>General Deactivation</td>
<td>31</td>
<td>14.903</td>
<td>14.548</td>
<td>0.467</td>
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</tbody>
</table>
Statistical significance of test data obtained for particular test scales was analysed using a Wilcoxon’s non-parametric pair ordering test. The results are summarised in Table 2.

<table>
<thead>
<tr>
<th>Hz</th>
<th>Test Conditions</th>
<th>N</th>
<th>Z</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>General Activation Before &amp; General Activation After</td>
<td>33</td>
<td>1.473</td>
<td>0.140</td>
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<td>High Activation Before &amp; High Activation After</td>
<td>33</td>
<td>0.732</td>
<td>0.463</td>
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<td>Deactivation – Sleep Before &amp; Deactivation – Sleep After</td>
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<td>2.151</td>
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<td>General Deactivation Before &amp; General Deactivation After</td>
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<td>0.955</td>
<td>0.339</td>
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<td>32</td>
<td>0.600</td>
<td>0.548</td>
</tr>
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<td>High Activation Before &amp; High Activation After</td>
<td>32</td>
<td>0.373</td>
<td>0.708</td>
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<td>Deactivation – Sleep Before &amp; Deactivation – Sleep After</td>
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<td>1.720</td>
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<td>General Deactivation Before &amp; General Deactivation After</td>
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<td>0.683</td>
<td>0.494</td>
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<td>1.581</td>
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<td>High Activation Before &amp; High Activation After</td>
<td>31</td>
<td>1.338</td>
<td>0.180</td>
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<td>Deactivation – Sleep Before &amp; Deactivation – Sleep After</td>
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<td>1.775</td>
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<td>General Deactivation Before &amp; General Deactivation After</td>
<td>31</td>
<td>0.822</td>
<td>0.410</td>
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</table>

*N* – group size; *Z* – Wilcoxon test value; *p* – statistical significance.

It appears that 20 min exposure to LFN wave with frequency $f = 7$ Hz and sound pressure level $\text{SPL} = 120$ dB (HP) is responsible for a statistically significant increase of the Deactivation-Sleep effect. Similar results are reported for the two other applied frequencies, though the increase was not statistically significant. Figures 1, 2, 3 show the

![Fig. 1. Variations of Deactivation – Sleep level ($f = 7$ Hz, $\text{SPL} = 120$ dB).](image_url)
plot of Deactivation-Sleep scale variations in the three test conditions. No statistically significant variations of the remaining Thayer test scales were found.

4. Discussion and conclusion

According to Thayer, self-assessment gives better information about the activation levels than single measurement of psycho-physiological parameters and, as such, might
be used as an excellent indicator in practical applications. Activation, as defined by
R.E. Thayer after long years’ research, involves single-dimensional aspects. Each di-
mension is associated with a separate physiological mechanism in various external con-
ditions, each has its own dynamics. These two types of activation are treated as inte-
grated psycho-physiological responses of the human body.

One dimension, underlying physical and cognitive activity, stretches from subjec-
tive feelings of energy and vigour right through to the opposite feeling: of sleepiness
and weariness. This dimension prompts human activity, makes the human body ready
for action and varies regularly, according to a 24 hours’ rhythm. The other dimension
stretches from subjectively felt tension right through to relaxation and quietness. It oc-
curs in emergency and hazard situations and is associated with subjective feelings of
anxiety and tension. This type of stimulation prepares the human body to act under
stress. When the tension is released, the person will feel relaxed.

Research data are indicative of a statistically significant enhancement of the deac-
tivation – sleep level in the conditions of low-frequency sound exposure ($f = 7 \text{ Hz}$,
sound pressure level $\text{SPL} = 120 \text{ dB (HP)}$. The number of points scored in this scale
goes up from 10667 to 11727. A similar trend is reported for $f = 18 \text{ Hz}$ and 40 \text{ Hz},
though these variations are statistically insignificant. No statistically significant varia-
tions of the remaining Thayer test scales were found.

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