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Localization of acoustic signals used in sound emitters at pedestrian crosswalks

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ABSTRACT

This study aimed at defining an optimal acoustic signal, which could be used in sound emitters at blind and visually impaired enabled pedestrian crosswalks. Two signals were identified from among three test groups of tested signals on the basis of psychoacoustic tests. These two signals met the following standard requirements: TR signal, a signal with a triangular temporal envelope and a sinusoidal carrier with a frequency of 880 Hz, repeated periodically with a frequency of 5 Hz, RC signal – a signal with a rectangular temporal envelope and a rectangular carrier with a basic frequency of 880 Hz, repeated periodically with a frequency of 5 Hz which were used to test the ability of a sound source to localize. The ability to localize was tested by a modified method ADHA (angle of directional hearing acuity) in which the 2AFC adaptation procedure was used. The test signals were emitted against the background of traffic noise:- non-moving and moving cars, - non-moving cars and moving trams and the ratio of the useful signal (65 dB SPL) to the noise (75 dB SPL) - S/N was -10 dB.The tests were conducted on 8 subjects with normal hearing (5 women and 3 men), aged 22-37 years (average 26 years). Statistical analysis of results obtained in the experiments led to the following conclusions: - localization is most difficult at the angles of 90° and 270°; dispersion of results is significant, - RC signals are better localized than TR signals- individual subjects differed considerably with respect to ADHA values.

INTRODUCTION

Directional hearing is philogenetically older than other functions performed by ears, such as perception of speech, music and different environmental sounds. The problem becomes more and more significant in present times when people are constantly exposed to acoustic stimuli, which are different with respect to their quality and intensity. In the environment, in which sounds are produced and where they propagate, each man is exposed to them, constantly hears the surrounding environment and to a larger or smaller extent is able to localize a given sound in space. The problem of localization becomes particularly important in the case of urban noises, mainly transportation noises (sound sources are mainly represented by moving objects), when the life of disabled people and particularly blind or visually impaired people, is at stake.

The study was aimed at the identification of a signal, which could be used in sound emitters at pedestrian crosswalks. The optimal signal could be localized against the background of traffic noises.

METHODOLOGY

The ADHA (Angle of Directional Hearing Acuity) parameter was assumed as the measure which defines localization ability [1]. 2AFC method was used to determine the ADHA value.The study was conducted with a mobile loudspeaker system. The loudspeaker was fixed to an arm with a radius of 1.5 m and moved around a circle; the subject's head was positioned in the middle. The arm with the loudspeaker was positioned using a stepper motor. ADHA measurements were made for 8 azimuths in the horizontal plane at the height of subject's head in the range of 0°-360°, every 45°. The subject was seated in a chair with a special support, which prevented the subject from moving the head in an uncontrolled way (see Figure 1).

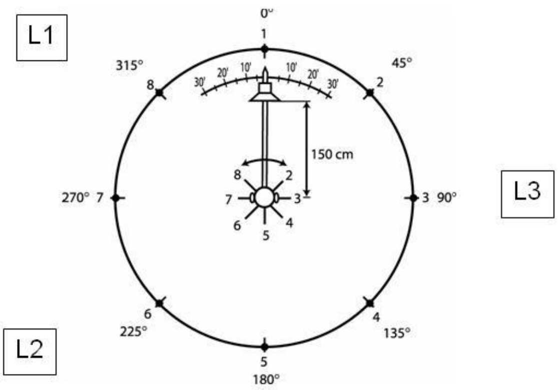

Figure 1. The subject's position with respect to the loudspeaker emitting a given signal

The loudspeaker generated 2 signals in a sequence, from 2 different positions. The value of the angle between successive positions of the loudspeaker in a single test was determined on the basis of the subject's responses and the rules of the adaptation procedure. After each pair of stimuli was generated, the subject was asked to say whether the second signal in the pair was to the right or to the left of the first signal. This is a new approach in such experiments, where the standard answers are "yes" or "no" depending on the subject's ability to differentiate between the directions from which the sound was emitted [2]. The 2AFC method is often used in psychological studies. Its basic form requires a "yes" or "no" answer. However, it can be assumed that the "left – right answer" method, used in localization studies, is more demanding for the subjects. The method requires the subject to verbally describe their subjective impressions, requires greater attention and concentration, and accidental answers are less likely [3]. In the experiment the 2AFC procedure with 6 turning points and an additive step was used: large additive step 4° and small additive step 1°. A single threshold was determined as an arithmetic mean of the last 4 turning points.

EXPERIMENTAL STUDY

On the basis of psychoacoustic investigations (annoyance estimation, detection of the threshold of signals presented in noise) conducted prior to the experiment two signals were identified, which met the standard requirements for sound emitters [4, 5, 6]

- TR signal – a signal with a triangular temporal envelope and a sinusoidal carrier with a frequency of 880 Hz, repeated periodically with a frequency of 5 Hz,
- RC signal – a signal with a rectangular temporal envelope a rectangular carrier with a basic frequency of 880 Hz, repeated periodically with a frequency of 5 Hz.

Time duration was 1.5 s and the interval between the signals - approx. 5-7 s.

The following types of transportation noises served as background signals:
- non-moving cars
- moving cars
- moving trams.

MEASUREMENT SETTING

ADHA values in the presence of background noises were measured in a setting, which is presented in Figure 1.

Loudspeakers L1 and L2 emitted a signal simulating noise generated by moving sources (cars or trams) and L3 loudspeaker emitted a signal simulating noise generated by a stationary source (non-moving cars). The experiments were conducted for the following configurations:
- non-moving cars and moving cars
- non-moving cars and moving trams.

The averaged level of traffic noise in the experiments was 75 dB SPL and the averaged level of test signals – 65dB SPL (SNR = -10dB).

The tests were conducted on 8 subjects with normal hearing (5 women, 3 men), aged 22-37 years (average 26 years).

The investigations were carried out in an anechoic chamber at the Institute of Acoustics, Adam Mickiewicz University, which meets the requirements of ISO 3745-1977.

RESULTS OF INVESTIGATIONS

The results are presented in Fig.2 and Fig.3.

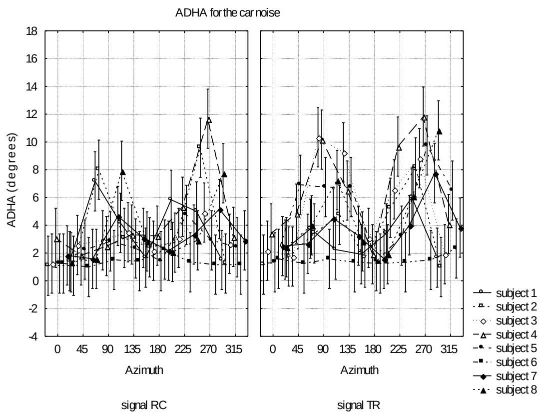

Figure 2. ADHA values for the car noise and individual subjects in the azimuth function and for the test signal type

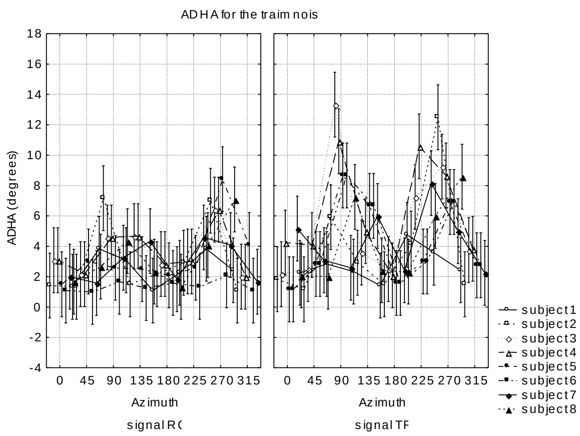

Figure 3. ADHA values for the tram noise and individual subjects in the azimuth function and for the test signal type

Following a statistical analysis (ANOVA variance analysis) it was found that there are no statistically significant differences in ADHA values depending on the type of the traffic noise. Figure 4 and Figure 5 presents ADHA results in the form of median, lower and upper quartile for all subjects but separately for each type of traffic noise and each type of test signal. The values of ADHA median for the sinusoidal signal with triangular envelope (TR) are higher than the value of ADHA median for a rectangular wave signal (RC). Such values were obtained for both the car noise (Figure 4) and the tram noise (Figure 5).

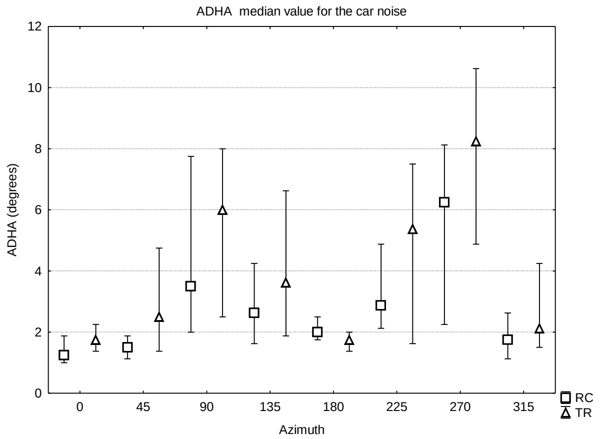

Figure 4. ADHA median, lower and upper quartile obtained for all subjects

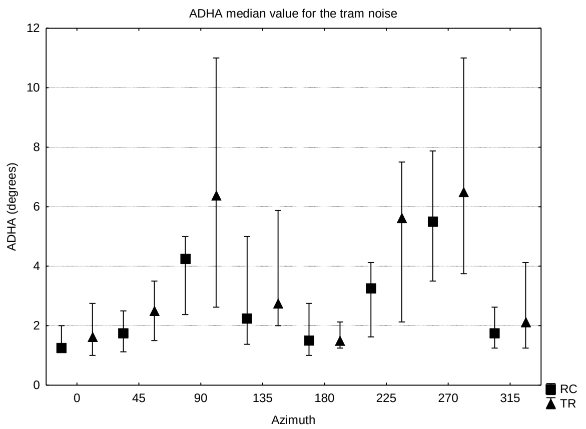

Figure 5. ADHA median, lower and upper quartile obtained for all subjects

A post-hoc test was conducted for the subjects. Tukey's test helped identify the largest homogenous group consisting of subjects nr 2,5,7,8. The variance analysis conducted for this largest homogenous group of subjects confirmed the absence of statistically significant differences between these four subjects.

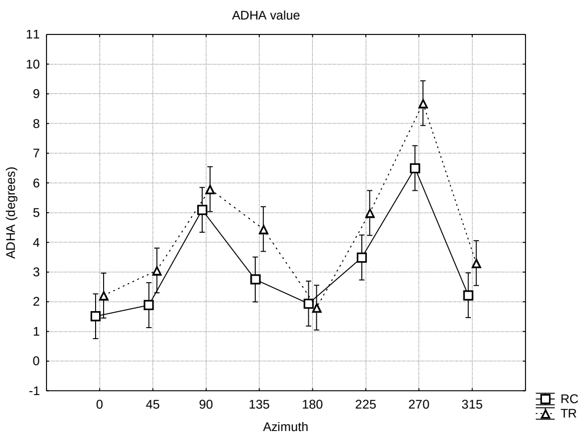

Figure 6. ADHA values averaged over noise and homogeneous group of subjects (2, 5, 7, 8)

It follows from the diagram in Figure 6 that a much better localization is obtained for the RC signal

CONCLUSIONS

The following conclusions can be drawn:

- there are considerable differences in ADHA values between individual subjects – they are clearly seen in the case of the TR signal, presented against the background of trams noise. The smallest differences were observed for the RC signal against the background of the same noise
- a multifactorial variance analysis revealed that there are no significant differences in ADHA values for both types of the traffic noise
- ADHA median values determined for all subjects are higher in the case of the TR signal, which indicates worse localization compared with RC signals
- following the Tukey's test, the largest homogenous group was identified, consisting of 4 subjects; the variance analysis confirmed the absence of statistically significant differences between these subjects
- ADHA values, averaged over noise and homogeneous group of subject, clearly indicate better localization of the RC signal compared to TR signal

ACKNOWLEGEMENT

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