MEASUREMENT OF DETECTION THRESHOLDS OF INTERAURAL TIME AND INTENSITY DIFFERENCES

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Abstract

Localization of sound source in the horizontal plane employs the evaluation of interaural time and intensity differences. The precision of the evaluating system depends on a number of parameters: frequency, overall intensity and deviation of the source from the medial plane. A preliminary psychophysical experiment was conducted to explore the intensity dependence of just noticeable time and intensity differences for the sound sources out of the medial plane.

1 Introduction

Localization of sound source in the horizontal plane depends heavily on the evaluation of two basic binaural disparities: interaural delay, also called interaural time difference (ITD), and interaural difference in sound level (ILD). These two localization clues are evaluated and encoded in dedicated neural circuits of mammalian brainstem. Mammals, including humans, are capable of surprisingly precise evaluation of ITD and ILD. The observed precision, however, is not constant over the whole frequency range and is also dependent on the angle, or azimuth, and overall stimulus intensity.

A number of psychophysical studies have been published that deal with the topic, the aim of our research was to investigate a less explored area of the state space – the intensity dependence of ITD and ILD detection thresholds for sound sources deviated from the medial plane.

The knowledge of the smallest detectable interaural disparities will help to design a more realistic psychoacoustic model utilizable in the systems for perceptual audio coding or methods for objective sound quality evaluation.

2 Stimuli and Methods

The total number of states to be measured was limited to 13 at the maximum. Harmonic signals with frequencies 250 or 1100 Hz were used for the measurement of ITD detection thresholds, the sensitivity to ILD was measured at 3000 and 9000 Hz. At each frequency, three intensities were used: 20, 50 and 80 dB above the hearing threshold. The initial interaural time delay was 500 μs in case of ITD measurement, the initial interaural intensity diference was 7,5 dB in case of ILD measurement. As an addition to the basic set of signals, a 250Hz signal at 50 dB with no interaural disparities was measured with respect to ITD sensitivity in order to compare our results to the results of previous studies.

Bursts of harmonic signals 1 second in length were used as the stimuli. A 2.5 ms raised cosine ramp was used both at the signal onset and the offset to minimize the disturbing effect of the onset and offset click. The stimuli were generated directly in the MATLAB environment with 16-bit resolution and 44.1 kHz sample rate. A professional RME FireFace 800 sound card was used for presenting the stimuli and for the precise intensity adjustment.

The subjects (three normal hearing humans between 20 and 30 years of age) sat in an attenuated chamber, the stimuli were presented with Sennheiser HD280 headphones. At first, the hearing threshold at the respective frequency was assessed using a simple interactive GUI. The sound pressure levels of the stimuli was then set relative to the hearing threshold. This way, the frequency response of the headphones, the possible temporary elevation of the hearing threshold and the current condition of the subject had almost no impact on the results.

The psychophysical method used was similar to that of Zwislocki [1]. For each selected point in the state space, a time separated measurement was conducted consisting of pairs of short stimuli, the first one being the reference. The second stimulus was presented with a slightly modified ITD or ILD, respectively. The subject had to judge whether the test stimulus was to the right or to the left of the

reference. In case when he could hear no difference he was instructed to guess. The range of the modified ITDs or ILDs covered the close neighbourhood of the point in the state space so that the smallest detectable change could be assessed. The stimulus pairs were presented in a random order, each pair appearing 20 times during the test. The percentage of correct answers was evaluated and the just noticeable ITD or ILD change was set to the value of 75 % of correct answers.

3 MATLAB Graphical User Interface

Both the hearing threshold measurement and the assessment of just noticeable binaural disparities utilized a MATLAB-based GUI and evaluating scripts.

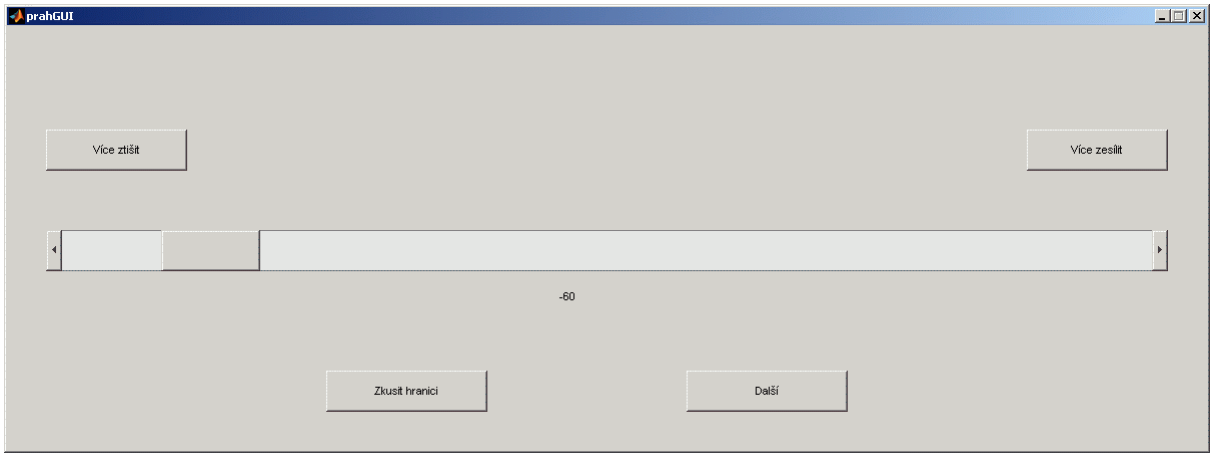

Figure 1: GUI for the measurement of the threshold in quiet.

The GUI for the measurement of the threshold in quiet is shown in Fig. 1. The subject sets the slider to the value where he can just hear the stimulus. The sound is played back any time the subject clicks the slider. The estimated threshold may be verified by pressing the "Zkusit hranici" button: two stimuli are played back, one that is 2 dB above and one 2 dB below the estimated threshold. The threshold is set correctly when the first and only the first stimulus is audible to the subject. The value of the threshold is saved to a standard '`.mat`' file.

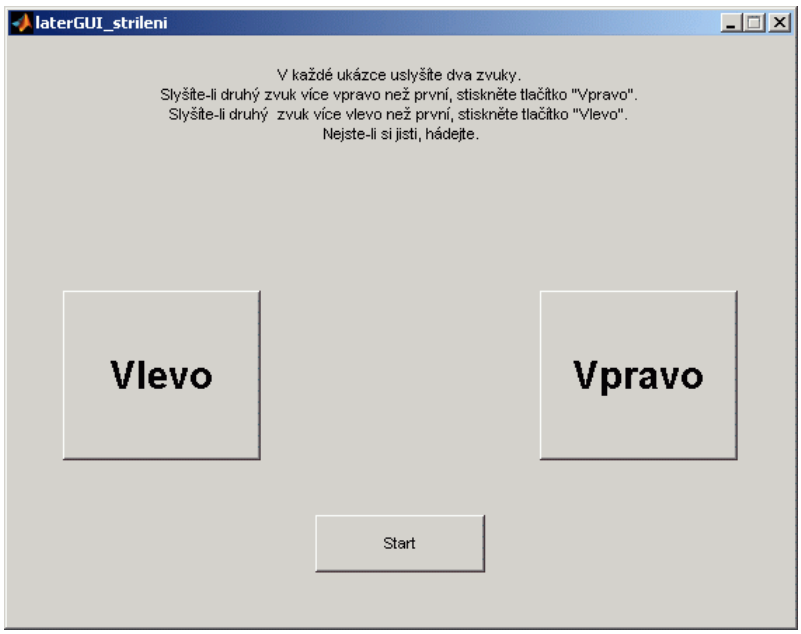

Figure 2: GUI for the measurement of the just noticeable interaural disparities.

The interface used for the measurement of the ITD and ILD detection thresholds is depicted in Fig. 2. After pressing the "Start" button, the subject is presented the stimulus pairs, as described

above, at the rate of 15 pairs per minute. The subject is instructed to press the “Vpravo” button in case he hears the probe more to the right than the reference, and the “Vlevo” button when he hears the probe more to the left than the reference. He is instructed to guess in case he can hear no difference in the location.

The sound playback was performed by means of the basic MATLAB `wavplay` routine. The stimulus intensity was controlled by the amplitude of the generated vector and also by the sound card settings. This enabled us to avoid using the more complicated Data Acquisition Toolbox routines while retaining the required dynamic range with only 16-bit depth.

The results of the test were saved to a standard ‘`.mat`’ file, the answer to each stimulus pair is either “Left” or “Right” or “Did not answer”. The number of correct “Left” and “Right” answers can be shown in a figure for visual inspection. An example of such a graph for the ITD detection threshold measurement is shown in Fig. 3. The just noticeable change of ITD can be estimated from the intersections of the response curves with the 75 % line.

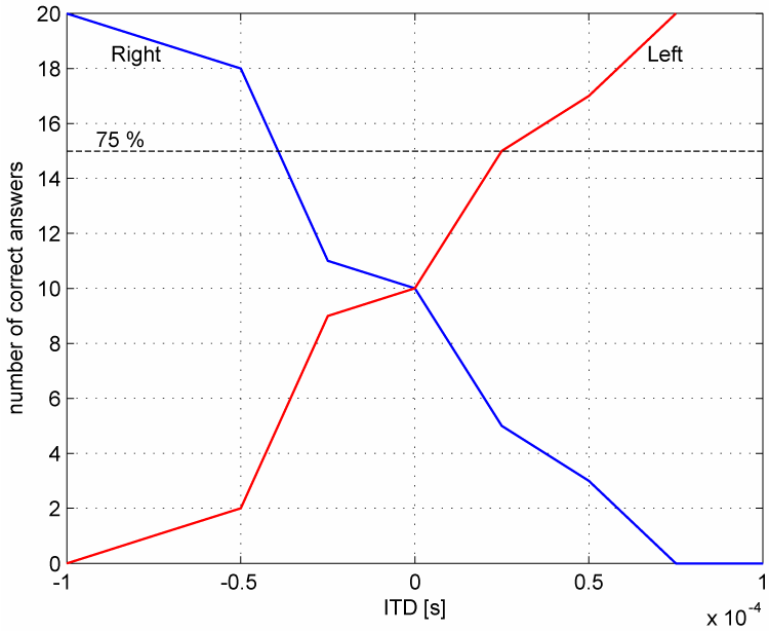

Figure 3: Number of correct “Left” and “Right” answers, dependence on the ITD modification.

4 Results

The results of the measurement are shown in Fig. 4. Generally, the intensity dependence of the ITD detection threshold has a convex shape, therefore the most precise evaluation of ITDs is observed at intermediate intensities. This result is in agreement with [1], showing that the ITD evaluation for the sources in and out of the medial plane is similar. The just noticeable ITD about the medial plane at 50 dB is also shown in Fig. 4 (green symbols). It is obvious that the deviation of the source from the medial place results in an increase of the detection thresholds. At 250 Hz the results of the three subjects are quite similar. At 1100 Hz only one subject was tested; a substantial elevation of the detection threshold relative to the 250Hz situation is apparent. At 20 dB the threshold became immeasurably high.

At 3000 Hz the three subjects show almost identical capabilities of the ILD detection. The curve has a downward slope indicating that the higher the overall intensity, the lower the ILD detection threshold. At 9000 Hz, however, the intersubject differences were more pronounced. It is known [2] that the spatial acuity at 9000 Hz is somewhat worse than at 3000 Hz, the reason being unknown. Our results seem to show that the ILD detection threshold at 9000 Hz increases with overall intensity.

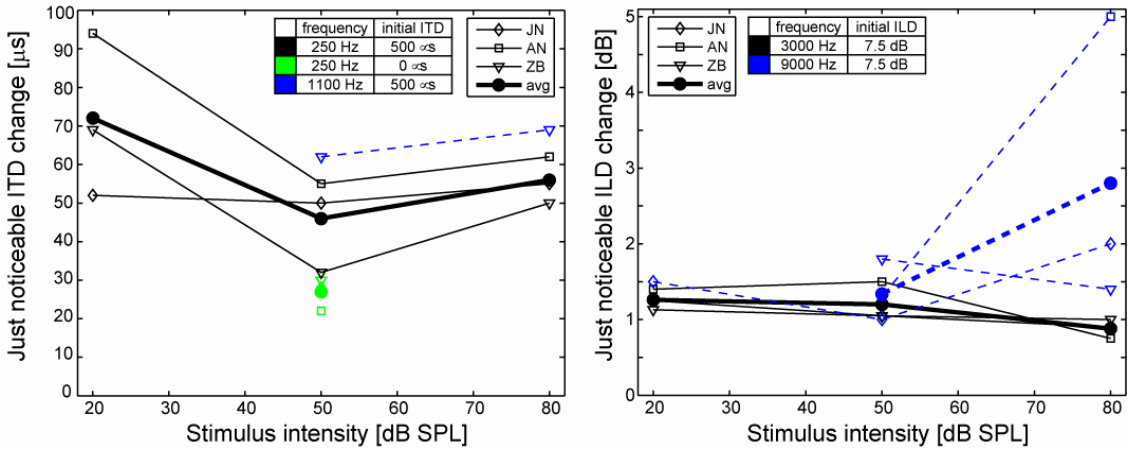

Figure 4: ITD and ILD sensitivity measurement. Open symbols: results for three subjects, filled symbols: mean value. Different parameter settings are shown in different color and line style.

5 Conclusion

A psychophysical experiment was conducted to assess the just noticeable changes in ITD and ILD for sound sources out of the medial plane. It was shown that the results are comparable to those with the source located in the medial plane, with a slight shift to higher values. It is noteworthy that the detectable amplitude differences may be as small as 1 dB, with direct implications for the perception of coded audio.

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References

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