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THE INFLUENCE OF SPECTRAL RANGE SIGNAL ON THRESHOLD DURATION OF PERCEPTION OF SOUND SOURCE RADIAL MOTION

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Accordingly the data received during last years (Brungart, Rabinowitz, 1999) binaural cues have to play essential role in sound source distance perception in near-field. The purpose of the study was to determine intensity or duration interaural differences are base of the hearing analysis of radial motion of sound image. The thresholds of duration necessary for identification of approaching and withdrawal sound images with various spectral range were compared in modeling sound source motion between two motionless dynamics placed in near and far fields. It was established that the duration threshold necessary for identification of approaching and withdrawal sound images was 191 ms in imitating motion by impulse consequences of wideband white noise and band noise in range of 3000 to 20000 Hz, in imitating motion by band noise in range of 200-1000 and 1000-3000 Hz – 291 ms. Thus, the value of the duration threshold depend on spectral range of sound source. The differences of the threshold values can be made clear by means of the high frequency mechanism of spatial hearing at what the hearing system analyzes intensity interaural differences.

Introduction.

The acoustical parallax for signals came to right and left ears arises in listening near sound sources (Hirsch, 1968; Greene, 1986; Lambert, 1974). The value of the acoustical parallax is maximal for sound sources placed along radius passed through pinna that means 90^o of azimuth. It diminished with arising of azimuth angle and for sound source placed at 90^o of azimuth angle the acoustical parallax is absent (Harley, Fry, 1921). Another reason of interaural differences is distortions of sound wave by pinna and depended on direction and distance between source and listener. The distortions of sound wave effected by both reasons and revealed in dependence of head-related transfer functions on distance between source and listener in near field. Head-related transfer functions have two components depended on spectrum and direction. First component described the amplitude change of signal, another was phase shift or time delay. The components were calculated and measured with help head manikin for distances from 0,12 to 1,0 m (Brungart, Rabinowitz, 1999). It was revealed on the basis of the data that interaural amplitude differences for distances in near field considerably increase for sound source placed at about 90^o of azimuth angles, but interaural time differences did not depend on the distance. That is why the binaural cues have to play essential role in perceiving of source distance in near field.

In measuring the duration thresholds necessary for identification of approaching and withdrawal sound images the increasing of its were revealed for radial motion at 90^o of azimuth in comparing with the thresholds for angles 0, 30, 45 and 60^o (Andreeva, Altman, 2000). This increase was about 25-35 % and indicated to important role of the sound wave direction maximally removed from the medial vertical plane. The comparison of our results with the above mentioned data on the role of binaural mechanisms in distance perception of near stationary sound sources allows us to propose hypothesis that the one of the binaural mechanisms of spatial hearing determines the value of threshold duration necessary for identification of approaching and withdrawal sound images. The aim of the study was to compare the thresholds of duration necessary for identification of approaching and withdrawal sound images with various spectral range.

Methods.

The study was fulfilled on six healthy subjects (two men and four women) with normal hearing, aging 17-38. The method of modeling approach and withdrawal of the sound source elaborated previously in our laboratory was used with some modifications. Trains of wide-band noise bursts (frequency range 20-20000 Hz) were used as stimulus. Radial sound source motion was created through linear, opposite in direction amplitude changes of the trains of wide-band noise bursts at two loudspeakers SONY XSF1720 placed at distances of 1,1 and 4,5 m from the listener in the anechoic chamber of the volume of 62.2 cubic meters at the eye level. The parameters of model impulse sequences and the schema of loudspeaker orientation were described in paper (Andreeva, Altman, 2000). Four series of signals differ by spectral range of noise impulses: first series consist of wide-band noise impulses in range of 20 to 20000 Hz; in the second series the impulses were the fragments of band noise in range of 200-1000 Hz; in the third series fragments of band noise in range of 1000-3000 Hz were used; in the fourth series - 3000-20000 Hz. The frequency range of band noise were chosen in accordance with the known mechanisms of binaural hearing: up to 1000 Hz -the localization process based on interaural duration differences, after 3000 Hz - interaural intensity differences, the range of frequencies between 1000 and 3000 Hz is that where both binaural mechanisms were not effective and the accuracy of localization in horizontal plane is small (Stevens, Newman, Mills, 1972). The intensity levels of the signals with different frequency ranges were 56-59 dB SPL.

The threshold measures were fulfilled in four series of signals. Each series included 140 signals of different duration (91, 141, 191, 291, 391, 491, and 791 ms) and movement direction presented randomly with three or five-second intervals between them. Azimuth angle was 0^o between the subject head and body position and direction of simulated movement. The subject was asked to give one of the following responses: a) the sound is approaching; b) it is withdrawing. Five sessions, each with four experimental series, were fulfilled with each subject. Threshold signal duration necessary for motion identification was determined as minimal duration corresponding to 75% of "correct" estimations of motion direction. The minimal signal duration define as minimal duration after that the probability of identification did not increased.

Results.

Summarazed results of 30 experiments performed on six subjects allow to determine the probability of radial motion direction identification for different duration of sound motion image. The probability of direction identification increases with increasing of signal duration up to 391 ms in all experimental series. The highest percent of direction identification was observed at series with impulse sequences of broad-band white noise and high frequency band noise. For these series the level of probability of direction identification did not change for stimuli duration of 391-791 ms. For the two other series the maximal value of probability was the same but with the increasing of signal duration the probability diminished from 93 % up to 86-89 %. Standard error for correct estimations determined over 30 experiments did not exceed 2%. Psychometric curves for four series showed in the figure 1.

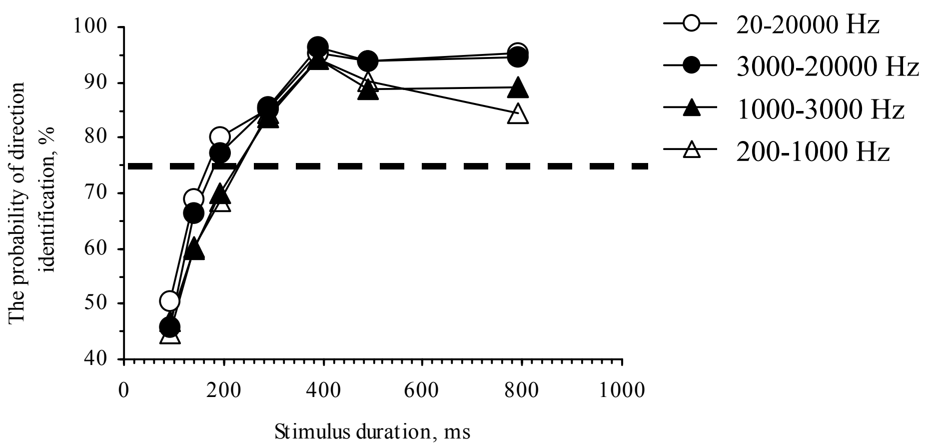

Figure 1. The probability of motion direction identification of sound image with various spectral range in dependence on sound duration.
X-axis – the probability of correct identifications, %; Y-axis – stimulus duration, ms.

Received psychometric curves allow to determine the duration threshold of motion direction perception for motion of sound images with different spectral range. Threshold signal duration necessary for motion identification was determined as minimal duration corresponding to 75% of identification probability shown in figure 1 by dotted line. The threshold duration for identification of motion direction (approach or withdrawal) during simulation of motion by means of impulses of white noise and noise with the band of range from 3000 to 20000 Hz was 191 ms, and noise with the bands 200-1000 and 1000-3000 Hz – 291 ms.

Discussion.

The model signals with the spectral range of frequency higher 3000 Hz were perceived with the shorter threshold of motion direction identification. That is the participation of high frequency binaural mechanism in auditory analysis of radial sound source motion evokes the decrease of its inertia. Two dynamics were used in the motion modeling, one of these placed in 1,1 m that the sound radiation were provided in near field. We proposed that the differences in head-related transfer functions for start and finish points of sound image trajectory can determined the perception of sound source radial motion. Using the data (Brungart, Rabinowitz, 1999) it can be proposed that these differences were revealed with the help of high frequency binaural mechanism of spatial hearing when the auditory system analyses the interaural intensity differences. It is known that the maximal sensibility to interaural differences was about 0 that defined the spatial location of dynamics and listener head. The sound stimulation in the frequency range lower 3000 Hz excluded the participation of high frequency binaural mechanism in sound motion analysis and the threshold duration increase up to 291 ms. The figure 1 and table 1 show that the signals included the frequency range higher 3000 Hz (white broadband noise and high frequency band noise) perceived with the lower threshold duration necessary for identification of approaching and withdrawal sound images.

Table 1. The values of thresholds of radial motion direction identification for different listening conditions.

Listening conditions		Duration threshold ms
Stimulus spectrum, Hz	Azimuth angle, grad	
White noise*, 20-20000	0	191
-“-*	30	191
-“-*	45	191
-“-*	60	191
-“-*	90	291
White noise, 20-20000	0	191
Band noise, 3000-20000	-“-	191
Band noise, 1000-3000	-“-	291
Band noise, 200-1000	-“-	291

*Accordingly the data (Andreeva, Altman, 2000).

The equal change of the duration threshold necessary for identification of approaching and withdrawal sound images were received and for sound image with spectrum without spectral range 3000-20000 Hz and for white noise signal at 90^o azimuth of radial motion (Andreeva, Altman, 2000).

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