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DETECTION AND LOCALIZATION OF SOUNDS BY HUMAN IN FREE FIELD CONDITION

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RESUME - On décrit les expériences psychoacoustiques concernant la localisation et la détection simultanées des tons 0,5 kHz et 4,0 kHz près du seuil de détection. On montre que dans ces conditions (1) la localisation est beaucoup moins effective que la détection et (2) les tons basse-fréquence sont localisés avec moins de précision que ceux haute-fréquence.

ABSTRACT - Psychoacoustical experiments on simultaneous detection and localization of 0,5 kHz and 4,0 kHz tones at near-threshold levels are reported. It is shown that (1) localization is accomplished much less effectively than detection and (2) near detection threshold low-frequency tones are localized with less accuracy than high-frequency tones.

In natural conditions the tasks of sound detection and localization are closely related; in psychoacoustic experiments, however, they are treated separately. This paper aims to investigate a problem of simultaneous detection and localization of sounds at levels close to detection threshold.

Experiments were carried out with six subjects aged 22-30 with no hearing loss. A subject was sitting on a seat placed on a metallic net in the centre of an anechoic chamber 12x12x9 m³ large. On the height of his ears seven identical loudspeakers were fixed uniformly on a semi-circumference $\pm\pi/2$, 3 m in radius, so that the angle between adjacent loudspeakers was $\pi/6$. The acoustic pressure at the placement of the head proved to be essentially the same for the loudspeakers fed by a reference electric signal. The experimenter and all the control circuits were located beyond the chamber; the subject and the experimenter communicated via a phone.

The listener, with his head immobile, had a task of detecting a signal from a loudspeaker and estimating its bearing. The 0,5 kHz and 0,4 kHz tonal pulses were used as stimuli.

At the first stage of the experiment detection thresholds for tonal pulses arriving from each of the seven loudspeakers were determined for all subjects. The pulse duration was 200 ms, the raise and fall times were 20 ms. A two-alternative forced-choice procedure was used at this stage: the signal appeared at random either in the first or in the second observation interval, both marked by light flashes. After each wrong answer the signal level was raised by 2 dB; after two correct answers in succession it was lowered by 2 dB. The

threshold was calculated by averaging the signal level over 15 inversions (the first three inversions were ignored). The threshold value determined by this procedure corresponds to the correct detection probability (CDP) value of 70,7% [1].

In the course of the main test session the signals arrived at random from different loudspeakers and the subject's task was to indicate both the presentation interval and the loudspeaker number. Hence, a two-alternative (for detection) combined with a seven-alternative (for localization) forced-choice procedure with no feedback was used. In each run, 200 trials having the same sound level were presented to a subject. For every run CDP and correct localization probability (CLP) were calculated. In order to provide a correct comparison between the results for two-alternative and seven-alternative procedure, sensitivity indexes d' [2] were calculated for detection and localization.

The results obtained show that all subjects had relatively high auditory sensitivity: the mean values of absolute thresholds for frequencies 0,5 and 4,0 kHz were as low as -2,3 dB SPL and -7,5 dB SPL respectively.

Such high sensitivity compared to that obtained with dichotic presentation of stimuli may be due to magnification effects in the outer ear. (Similar results were reported for sound detection by cat [3]). This effect manifests itself particularly at 4,0 kHz because at 0,5 kHz the influence of pinna and the shielding effect of the head are negligible.

The localization proved to be accomplished by the listeners much less effectively than the detection in the entire range of sound levels explored. In fig.1 CDP (solid line) and CLP (dashed line) values averaged over seven loudspeakers are shown as functions of sound level. It is evident that for all listeners a range of sound pressure exists in which detection is rather good while localization is highly erroneous. Furthermore, the CLP vs sound level curve grows much steeper for 0,5 kHz than for 4,0 kHz tones. Hence, in the near-threshold range low-frequency tones are localized considerably better than high-frequency ones. The same conclusion may be drawn from the analysis of fig.2 where corresponding d' values are plotted. We relate this effect to the fundamental difference in physiological mechanisms of sound localization in high-frequency and low-frequency regions. It is well known that the main criterion for localization of low-frequency tones by the auditory system is the interaural delay of carrier cycles. The latter is coded by the delay of neural spikes in the left and right fibers of the auditory nerve. The accuracy of temporal coding is known to remain fairly high even at the lowest signal level. Moreover, at optimal frequency, the excitation phase is very little level-dependent [4]. This allows to suggest that the interaural delay analysis can remain quite effective down to threshold stimulus levels.

At 4,0 kHz the carrier temporal pattern is hardly followed by the nerve fibers, and the main localization criterion becomes the interaural level rather than time difference. In the low-signal range the difference limen for tones is known to be very high and diminishes only gradually with increasing sound level. So, in this level range, the temporal localization mechanism acting at low frequencies seems to be more reliable than the amplitude one used for high-frequency tones.

The results mentioned above were obtained by data averaging over all loudspeakers. However, in near-threshold conditions, the

Fig. 1

Fig. 2

Fig 3

analysis of the auditory perception peculiarities related to the spatial location of sound sources is of considerable interest. So, for each loudspeaker a 'preference factor' (PF) was evaluated, numerically equal to the ratio of overall trials number a particular loudspeaker was pointed out by a subject (no matter whether correctly or wrongly) to the actual number of signal presentations through this loudspeaker. PF values averaged over all subjects are presented on fig. 3 as function of source azimuth for 0,5 kHz (the solid line) and 4,0 kHz (the dashed line) tones. For each subject, the data used correspond to the signal level 2 dB higher than the subject's individual detection threshold. The curves of fig.3 suggest that for low-frequency signals the preferred directions correspond to the left-hand side and for high-frequency ones - to the right-hand side position of the sound source. A pronounced edge effect is also evident - a drastic fall of PF values towards marginal loudspeakers located at $\pm\pi/2$ with respect to sagittal plane. These effects proved to be quite stable and well noticeable even at the highest levels of the signals used.

Finally, the effect of flash light location on localization efficiency was noticed: the subject's attention was drawn to a definite azimuth by a flash of light which source was attached to the corresponding loudspeaker (the head did not move). As a result, some rise of CDP and CLP values for directions of visual tuning was revealed, particularly at 4,0 kHz. Similar effect was recorded earlier by the author and investigated in detail for broadband signals with bandwidth (0,1 - 12,0) kHz using different methods of listener's concentration [5,6]. Additional experiments showed that for signal having narrower bandwidth (0,1 - 5,0) kHz, the effect persist but the influence of the subject's tuning is reduced.

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