DURATION THRESHOLD FOR TONE-PITCH AS A FUNCTION OF THE INITIAL PHASE OF THE TONE PULSES

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The present contribution summarizes the results of measurements of the dependence of the initial phase of the tone pulses upon the duration threshold for tone pitch for frequencies of 250 Hz, 1000 Hz and 4000 Hz and for two values of the initial phase, namely 0° and 80°.
The results of experiments have indicated that the initial phase parameter affects the tone-pitch duration threshold in such a way that the tone pitch duration threshold is longer at the initial phase of 80° than at 0°. This dependence is most striking at the frequency range of 250 Hz, however, it can hardly be observed at the frequency of 4000 Hz.

I. INTRODUCTION

One of the characteristic quantities playing an important role in the auditory system description is the tone-pitch duration threshold [1]. There are several experimental ways of measuring the tone-pitch duration threshold as a function of the loudness and frequency [2, 3, 4, 5]. The frequency dependence of the average duration threshold value is represented in Fig. 1.

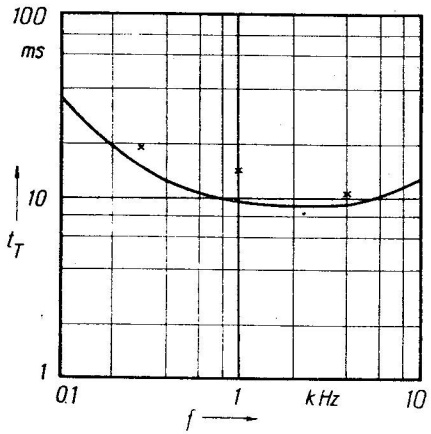

Fig. 1. The frequency dependence of the mean values of the duration threshold for the tone-pitch at random initial phases of tone pulses (the full line is the image of the function $t_T = 9.5/[1\text{-}\exp(-f/f_0)]$ within the range of 0.1 kHz to 4 kHz and $t_T = 10^2/(12.1 - 4.21 \times 10^{-4}f)$ within the range of 4 kHz to 10 kHz, where $f_0 = 300$ Hz). Results of our experiments (at the initial phase of 80°) are plotted in Fig. 1.

In all the measurements that have been performed so far, the tone pulses have had a not exactly determined initial phase. As shown by the experiments described in [6], the initial phase plays an important role in the tone pulse perception. That is why we have considered it important to find out the following facts experimentally:

a) The tone-pitch duration threshold of tone pulses with an exactly defined initial phase; *b)* the duration threshold for the tone pitch as a function of the initial phase.

II. METHOD AND PROCEDURE

In all measurements the combined method of limits was employed. Every three minutes a tone pulse was presented to a subject. During a series of measurements all pulse parameters coincided except the duration. The subject changed the pulse duration himself within an interval of one or more periods. At the beginning the subject tuned a potentiometer, by means of which he changed the pulse duration, into a position where the pulse had the character of a distinct click (noise), and thus it was impossible to determine its pitch. Then the subject left the control potentiometer in this position an gave an optic signal to an operator, who recorded the pulse duration — one crossing point within the framework of the measurement by the method of limits. Next the subject tuned the potentiometer to the position in which the pulse was likely to be of a tonal character, and he was gradually shortening the pulse duration until the tonal character was missing. In this position of the potentiometer the subject gave another optic signal to the operator, who recorded the signal duration as the second crossing point. The average value of the two crossing points in the sequence was considered to be one value of the tone-pitch duration threshold of pulses.

Five students aged 22 were chosen for experimental measurements. They were examined audiometrically and afterwards explained the experimental procedure and technique. Each subject carried out 6 ascending and 6 descending measurements at the pressure level of 80 dB, at frequencies of 250 Hz, 1000 Hz and 4000 Hz, the initial phases being 0° and 80°.

III. APPARATUS

The block scheme of the experimental apparatus is shown in Fig. 2. At the beginning of this chain there is a tone generator (*TG*) Brüel Kjaer, from which

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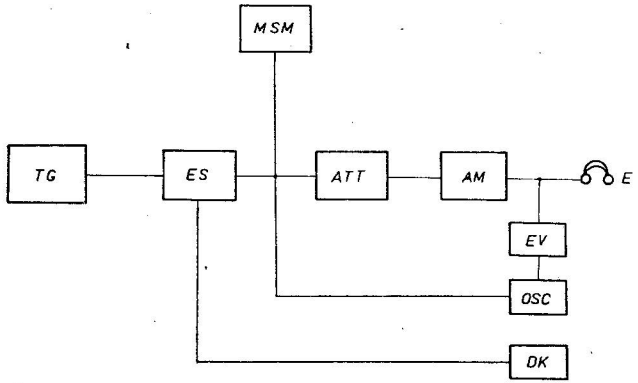

Fig. 2. The block scheme of the apparatus.

sinusoidal voltage was passed into an electronic switch (*ES*), cutting tone pulses out of it in a prescribed time sequence, their initial phases being determined.

Havig passed the attenuator (*ATT*) RTF Xa 714, the pulses were further led through the adjusting member (*AM*) into the ear-phone (*E*) Beyer RT 96. The pulse duration was checked by means of a millisecondmeter (*MSM*) Radiometer. The pulse parameters at the input of the ear-phone were controlled by an electronic millivoltmeter (*EV*) Tesla BM 384 and gauged oscilloscope (*OSC*) Křižik D 581. The subject changed the pulse duration by means of remote control (*DK*).

IV. EXPERIMENTAL RESULTS

The results of our experiments are summarized in Tables 1, 2 and shown in Fig. 1. In the first column of Table 1, the subjects are denoted by the Roman numerals I—V, in the second there are the initial phase of tone pulses. The statistically determined results of the tone-pitch duration threshold of individual subjects at the frequency range of 250 Hz, 1000 Hz and 4000 Hz, the initial phase being 0° and 80°, given in milliseconds, are placed in the third, fourth and fifth columns.

The frequency range of the examined pulses is introduced in the first column of Table 2, the initial phases are in the second column; the third column contains values of the average tone-pitch duration thresholds of all the five subjects; the fourth contains standard deviations.

Table 1

Subject	Initial phase	250 Hz	1 000 Hz	4 000 Hz
I	0°	20.00 ± 2.31	12.00 ± 0.81	9.71 ± 0.41
	80°	24.00 ± 2.30	13.33 ± 1.24	10.10 ± 0.79
II	0°	15.33 ± 2.72	10.83 ± 1.24	9.07 ± 0.20
	80°	17.76 ± 0.75	13.83 ± 0.62	9.23 ± 0.52
III	0°	12.83 ± 1.57	10.08 ± 1.54	9.91 ± 0.74
	80°	16.50 ± 2.35	12.92 ± 1.20	9.62 ± 0.63
IV	0°	12.67 ± 0.80	11.58 ± 1.97	10.53 ± 1.16
	80°	15.00 ± 2.23	13.16 ± 1.38	11. 24 ± 1.36
V	0°	18.33 ± 1.37	13.00 ± 1.35	12.83 ± 1.32
	80°	20.32 ± 1.12	16.83 ± 1.68	12.72 ± 1.27

Table 2

f [Hz]	φ_0	Duration threshold for the tone-pitch [ms]	σ [ms]
250	0°	15.83	2.67
	80°	18.72	2.89
1 000	0°	11.50	1.04
	80°	14.01	1.45
4 000	0°	10.41	1.29
	80°	10.58	1.60

We can see that the initial phase of 0° exactly established, the observed tone-pitch duration threshold does not differ essentially from the average tone-pitch duration threshold value measured at random initial phase of the tone pulses.

On the other hand, the tendency of an increasing tone-pitch duration threshold can clearly be observed at the initial phase of 80°. This tendency is clearly visible at the frequency value of 250 Hz, where it reaches the value of 3 ms, while the increasing tone-pitch duration threshold at the frequency of 1000 Hz is substantially shorter, and that at the frequency of 4000 Hz is negligible.

V. THEORETICAL ASPECTS

The increase of the tone-pitch duration threshold due to the initial phase is a phenomenon which can be explained by means of the place theory of audition. According to this theory the tonal character of the pulse is determined by its bandwidth. Since the bandwidth increases when the initial phase of the pulse increases, the dependence of the tone-pitch duration threshold increase

on the initial phase, which has been observed, is in agreement with the place theory of audition. On the other hand, no such mechanism is known within the telephone theory which would explain this effect.

As it was shown in [7], the tone-pitch duration threshold is connected with another characteristic bandwidth of the ear, with the standard deviation of the frequency values, which were determined by means of the method of matching with the test signal of a given frequency. Therefore there holds:

$$\frac{\sigma(f, t_T(f))}{f} = 4.4 \times 10^{-2}$$

where $t_T(f)$ is the tone-pitch duration threshold at the frequency f. The numerical value on the right-hand side of the equation was determined from the average value of the tone-pitch duration threshold. Since this relation plays a very important role when the information-theoretical capacity of the ear is to be determined, its verification would mean a remarkable progress in the detection of its information-theoretical properties. This can be achieved only by further, more detailed, measurements of different combinations of the parameters of tone pulses.

VI. CONCLUSIONS

The results of our experiments can be formulated as follows: 1. the tone-pitch duration threshold depends also on the initial phase of tone pulses; 2. at the initial phase of 80°, the tone-pitch duration threshold is longer at the investigated frequencies than it is at the initial phase of 0°; 3. the tone-pitch duration threshold increase depending on the initial phase is more distinct at the frequency of 250 Hz than the frequency of 1000 Hz; the initial phase influences negligibly the tone-pitch duration threshold at the frequency of 4000 Hz.[1]

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[1] The measurements carried out by us represent only the first part of the work, the aim of which is to determine the initial phase influence on the sensory characteristics of the acoustic stimuli. In our further work we shall be dealing with the determination of the experimental relations between the duration threshold for the tone-pitch and the initial phase of the tone pulses.

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