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TIME ERROR IN PERCEPTION OF SOUND BRIGHTNESS

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The paper presents the results of experiments in perception of sound brightness. The purpose of the investigation was to define paired comparison conditions in which the time error (TE) occurs. The duration of the interstimulus interval (ISI) between two white noise signals was used as an independent variable. No TE was observed for ISI of 0.1-2 s. A small negative TE occurred for longer ISI (4-8 s). Similar results were obtained for the noise stimuli limited in the low and high frequency range.

1. Introduction

One of the basic tasks of psychoacoustic experiments is to determine the thresholds of human auditory perception. As a threshold we understand the boundary separating stimuli producing one kind of human sensation from another. One of the standard methods used in threshold investigation is paired comparison procedure. When this method is applied the "time error" (TE) may be observed. The term *time error* refers to the systematic asymmetries that commonly arise in comparisons between stimuli which are presented pairwise, separated by a time interval. Numerous investigations have provided evidence that the TE is dependent upon several stimulus factors, particularly the length of the interstimulus interval (ISI), the level of stimulation etc. A sequential comparison of stimuli makes the evaluation dependent on both memory and masking factors. It can be generally assumed that the significance of the memory factor increases as the ISI increases and the significance of the masking factor is the greatest for short ISIs. The minimalization, or, at least, the knowledge of the character of the TE, is necessary to draw valid conclusions from the results obtained.

In the design of the test special control tasks in which both of the stimuli compared are objectively the same are used to disclose the TE character. TE is assumed as equal to zero when both stimuli in control tasks are judged as identical by the listeners. TE is assumed to have a negative or positive value if the investigated feature in the first stimulus is under- or overestimated, respectively, in relation to the second.

Some data on the auditory time errors for loudness and pitch perception can be found in psychological and acoustic literature. As for the loudness the first information on this subject was given by KÖHLER [3], who noticed a positive TE for ISI of 1.5 s, practically zero TE at 3 s and a negative TE at 6 and

12 s. POSTMAN [8] obtained fairly similar results founding a positive TE for ISI of 1 and 2 s but a negative TE with longer intervals (4 and 6 s). In 1954 POLLACK [7] carried out a very extensive study on the loudness perception confirming the general character of the TE as had been determined by the previous workers. However, the range of ISI values in which TE ≈ 0 was found as lying slightly lower than had been assumed before. Depending on the method used to compare stimuli and the experimental setting, the time varies from 0.65 s to 2.5 s (1.25 s on the average). A similar conclusion can be drawn from NEEDHAM's paper [6] (TE = 0 for ISI of 1-1.5 s).

When the pitch of tones is judged there is no agreement between investigators as to the existence of TE. TRUMAN and WEVER [9], KOESTER [4] and POSTMAN [8] carried out several series of investigations using various methods. Neither of these investigators was able to demonstrate any time error, positive or negative, for any of their subjects for ISIs shorter than 6 s. These results, however, are in disagreement with the observations of MASSARO [5], JAROSZEWSKI and RAKOWSKI [1], who have shown the existence of a positive TE for ISI shorter than 300 ms.

All the data mentioned above deal with the TE in the case of two physically identical stimuli being compared. When pairwise stimuli differ from one another in respect of an investigated feature, the listeners have an additional tendency to overestimate the existing difference both in the loudness and in the pitch perception tasks.

However, there are still no data on the TE occurring in a sequential comparison of sound timbre. This became especially important nowadays due to an increasingly wide interest in multidimensional scaling of timbre and the development of sound quality evaluation method. For that reason an experiment on the TE for timbre perception was carried out. In regard to preliminary assessment of this problem subjects were only questioned on one dimension of timbre, namely brightness of sound.

2. Procedure and results

Wide band noise was the signal in the experiment. Two seconds long samples of the signal were paired compared in respect to brightness of sound impression. In each sequence two stimuli were separated with ISI equal respectively to 0.1, 0.2, 0.5, 1, 2, 4 and 8 s. The test consisted of 84 trials. A white noise signal was a reference stimulus (designated "0"). For each value of ISI four "0–0" type test sequences were presented (28 trials). In the other trial sone of the stimuli was high-pass or low-pass noise with cut-off frequency respectively 14.1 kHz (signal "1") or 11.2 kHz (signal "2") and 141 Hz (signal "3") or 178 Hz (signal "4"). All high- and low-pass signals were produced from the reference stimulus with the help of Brüel-Kjaer Spectrum Shaper 5587. All sequencies 0–1, 1–0, 0–2, 2–0 etc. were presented once for each

of the investigated ISI values. All 84 trials in the test were presented at random. The pause between successive trials was equal to 5 s. Each trial was preceded by a short pulse of 1 kHz sine wave. The duration of the whole test was about 16 minutes.

The test was recorded on and played back from — Revox *A77* tape recorder. Test signals were reproduced with the help of two parallelly working "Fonia" GK-132 sound monitors. The frequency range of electroacoustic chain was equal to 40-18000 Hz±3 dB. The sound control room at the Chopin Academy of Music in Warsaw was used as a listening room.

The test was presented at loudness level of 80 phones. The subjects were 15 students and faculty members of the Sound Recording Department. All subjects had normal hearing acuity and some previous experience in psychoacoustic experiments. The age ranged from 20 to 35 years. The listeners' task was to determine which of the two stimuli in each trial was perceived as "brighter". The subjects could not answer: "I don't know" or "Both stimuli are identical".

The results obtained are presented in Tables 1 and 2. Based on Tables 1 and 2, a statistical analysis of the results was performed. Experimental results were compared against the hypothesis that the choice of the first or the second signal in a pair was equally probable. The test for significance of a proportion

Table 1. Experimental results for "0-0" type trials

ISI [s]	Proportion of the choice of the first or the second stimulus in a pair	The value of z statistics
0.1	27 : 33	−0.77
0.2	34 : 26	1.03
0.5	33 : 27	0.77
1.0	35 : 25	1.29
2.0	25 : 35	−1.29
4.0	20 : 40	−2.58
8.0	18 : 42	−3.10

Table 2. Experimental results for mixed pairs trials

ISI [s]	Proportion of the choice of the first or the second stimulus in a pair for trials							
	0–1	1–0	0–2	2–0	0–3	3–0	0–4	4–0
0.1	13 : 2	1 : 14	14 : 1	1 : 14	1 : 14	15 : 0	0 : 15	15 : 0
0.2	12 : 3	1 : 14	14 : 1	0 : 15	0 : 15	15 : 0	1 : 14	15 : 0
0.5	13 : 2	4 : 11	15 : 0	0 : 15	0 : 15	14 : 1	1 : 14	14 : 1
1.0	9 : 6	4 : 11	15 : 0	0 : 15	0 : 15	14 : 1	1 : 14	14 : 1
2.0	9 : 6	1 : 14	14 : 1	0 : 15	0 : 15	14 : 1	1 : 14	15 : 0
4.0	10 : 5	4 : 11	15 : 0	0 : 15	0 : 15	12 : 3	1 : 14	12 : 3
8.0	9 : 6	2 : 13	15 : 0	0 : 15	2 : 13	11 : 4	0 : 15	13 : 2

(z-test) was made at a significance level $\alpha = 0.1$ [2]. The results are presented in the third column of Table 1. The z-values obtained for ISI of 0.1-2 s satisfied the condition $|z_{emp}| < z_{0.05} = 1.645$ indicating the lack of the TE for the evaluation of sound brightness.

For ISI equal to 4 and 8 s, $|z_{emp}| > z_{0.05} = 1.645$ indicates the occurrence of the TE under the experimental conditions.

The results presented in Table 2 testify that all four low- and high-pass conditions had distinctly audible character. It was the most difficult in terms of sound brightness to distinguish "1" from "0" signals. Error distribution in 0—1 or 1—0 (30 : 17) and 0—3 or 3—0 (3 : 20) sequences indicates that listeners generally tended to evaluate the second stimulus in the pair as brighter. The differences in errors are significant at a level $\alpha = 0.1$ in both cases. This observation agrees with the results of the analysis for "0—0" type trials.

3. Discussion

The data shown in Tables 1 and 2 indicate the lack of the distinct TE for sound brightness for ISI of 0.1-2 s. The error distributions obtained for "0—0" conditions prove the random distribution of responses. Longer ISIs indicate the existence of negative value of the TE. One can state that the subjects overestimate brightness of sound for the second stimulus. It seems to justify the hypothesis that auditory memory is better for lower than for higher components of the spectrum. This hypothesis requires, however, to be confirmed by subsequent experimental investigations.

For mixed pairs of stimuli the subject perceived correctly all differences in brightness. The total number of errors did not exceed 10% (76 errors). Moreover, the distribution of errors shows that the difficulty of the test increases according to the value of ISI.

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