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VARIABILITY OF THE HEARING THRESHOLD TRACINGS IN AUTOMATIC AUDIOMETRY BEYOND THE INITIAL TRANSIENT PHASE

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The results of measurements and the analysis of variability of the hearing threshold observed in automatic audiometry beyond the initial transient phase are given. The methods of interpretation of the threshold tracings and their adequacy with respect to various rates of the test signal level control are discussed.

1. Introduction

It is well-known that the hearing threshold level in individuals is far from being constant even if the temporary threshold shifts due to exposure to high intensity sounds is not taken into account [1, 2, 3].

Beyond the initial transient phase in the tracing, which, with regard to its presumable origin and dependency on the experimental conditions has been discussed in the previous report [10], the hearing threshold undergoes fluctuations resulting from a number of various factors. Among these factors in the earlier studies three main groups were recognized, i.e. physiological (heart action, blood pressure, body temperature, degree of fatigue etc), physical (atmospheric pressure) [4] and psychological such as short term variations of the reaction time and changes in the threshold detection criteria as well as practice and motivation in the subjects [5, 6, 8, 13, 14].

Threshold level depends also in a considerable degree on the pattern of presentation of the stimuli, particularly on the rate of signal level control and on the duration of the measurement. Corso's findings [5, 6] which do not reveal substantial influences of neither the rate of signal level control nor the duration of the measurement were not to the authors' knowledge confirmed in the observations by other authors. Some implications leading to the conclusion contradictory to the results reported in Corso's works can be inferred from the data published by Hempstock et al. [7]. According to these data, after the elapse of abt. 15 min from the beginning of the measurement, the difference in hearing thresholds for the continuous and the interrupted tone amounts to abt. 5 dB. Also from Zwislocki's et al. [14]. report it is evident that the hearing threshold level, as determined by Békésy's audiometer tracings, is clearly dependent on the duration of the measurement.

In the analysis of the figured factors influence it should be remembered that the signal level taken as a hearing threshold level results from the definite statistical operation and hence depends on the convention applied. In automatic audiometers (Békésy type audiometers) this comes to the method of interpretation of the hearing threshold tracings in the attempt to determine these values of the signal level which are taken as the hearing threshold level.

In conventional clinical audiometers in which signal level is controlled manually, the rate of signal level control near the threshold is usually quite small, of the order of 0.5 – 3.0 dB/s. Also the effective duration of the measurement at the separate discrete frequencies usually does not exceede a few seconds. It should be pointed out that as an effective duration of the measurement only this time span should be understood in which the subject is able to detect the test signal which, as a matter of fact, usually has near the threshold level.

Obviously enough quite different situation is faced by the listener in case of the automatic audiometers being applied, particularly these equipped with the electronic control of the signal level [9, 11, 12]. In these audiometers the rate of signal level control can be varied in a very wide range. Quite substantial changes in the hearing threshold tracings follow these variations and result in the changes of the hearing threshold level read out from the tracings according to the applied convention pertaining to the averaging of the spikes recorded.

Hence a question appears what rates of the signal level control can be applied and what criteria should be used for the determination of the threshold level from the threshold tracings thus obtained. Particularly it seems to begin questionable if the commonly used method of the linear interpolation can be applied both for low and high rates of the signal control and which phase of the tracing should be regarded as representative for the «true» threshold. The answer to these questions is the attempt of this work. Just to illustrate the divergency in the results of the threshold measurements obtained from automatic audiometry (conventional averaging) and conventional audiometry (the method of limits) which amounts to about 3 dB the report by Hempstock et al. [7]. can be quoted.

2. The equipment and method

The measurements were made in the sound insulated booth using the Békésy type automatic audiometer with the electronic control of signal level, described in detail in the earlier reports [9, 11, 12]. The last version was used with the threshold equaliser, TDH 39 MX 41–AR headphones and the headphones frequency response equaliser. Continuous sine signal test stimulus of fixed frequency was used in all the measurements (automatic frequency scanning disconnected) and the discrete frequencies in the successive experiments were 100, 1000 and 8000 Hz. At each of these frequencies the hearing threshold level tracings were made using three rates of the signal level control i.e. 3, 10 and 30 dB/s.

Three music students, two male and one female, aged 24 to 26 otologically normal and with considerable experience in similar experiments served as subjects in the experiments. The measurements were made in individual sessions with each of the subjects who performed in accordance with the known instructions for automatic audiometers [10]. The test signal was delivered to one ear only. Before the actual measurements each listener was obliged to stay in the closed booth for 10 min to reduce the effect of the hearing threshold improvement in silence [3]. The duration of the threshold tracing in all cases was at least 12 min. In this manner several threshold tracings from each listener were obtained each day. Rest periods between the successive tracings were about 30 min. At the beginning of each session listeners had to pass the routine screening test i.e. test threshold tracing at 1 kHz and 3 dB/s. If the mean threshold level traced varied more than ± 1.5 dB the measurements were not continued that day.

The experiment was carried out over the span of three months but the measurements with individual listeners lasting about 1 month were made in succession, so as to collect the individuals data within the possibly short period. The number of tracings from each of the listeners was 10 at 9 points defined by 3 frequency and 3 signal control rates combinations.

3. Data processing and the results of analysis

From each of the hearing threshold tracings thus obtained the fraction from the very beginning up to 60 s was eliminated as pertaining to the initial transient phase [7]. Next, from each 10 s of the tracing over its whole length the mean values L_s and the maximum values L_m of the recorded level were determined, in each case the appropriate method of averaging being applied (i.e. L_s – averaging between the extremes of the record; L_m – averaging between the maximums of the recording).

These data, pertaining to 9 experimental situations (3 frequencies, 3 signal control rates at each frequency) were gathered in assemblages of L_s and L_m containing information referring to the successive 60 s time spans. The assemblages contained 180 L_s and 180 L_m readings (6 readings $\times$ 10 tracings $\times$ 3 listeners = 180). Medians and maximal deviations of L_m and L_s determined from these assemblages are presented in Fig. 1 and Fig. 2.

The overall «by eye» analysis of the $L_s(t)$ and $L_m(t)$ functions reveals quite considerable variability of the hearing threshold level with time and also its dependence on the rate of signal level control. It can be observed at all the three frequencies and all signal control rates used. Therefore it had to be de-

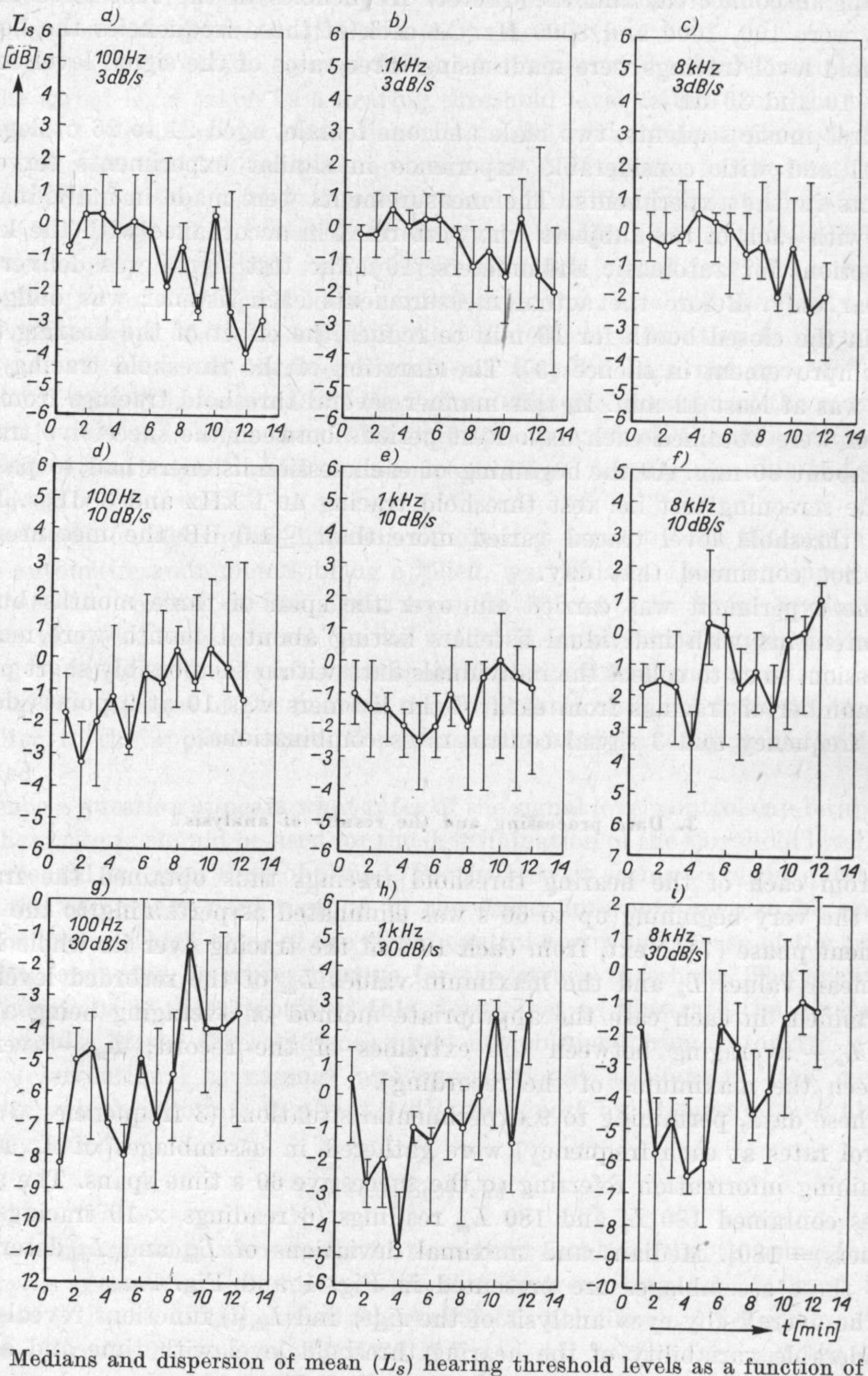

Fig. 1. Medians and dispersion of mean (L_s) hearing threshold levels as a function of time. Frequencies 100, 1000, 8000 Hz; rates of test signal control 3, 10, 30 dB/s

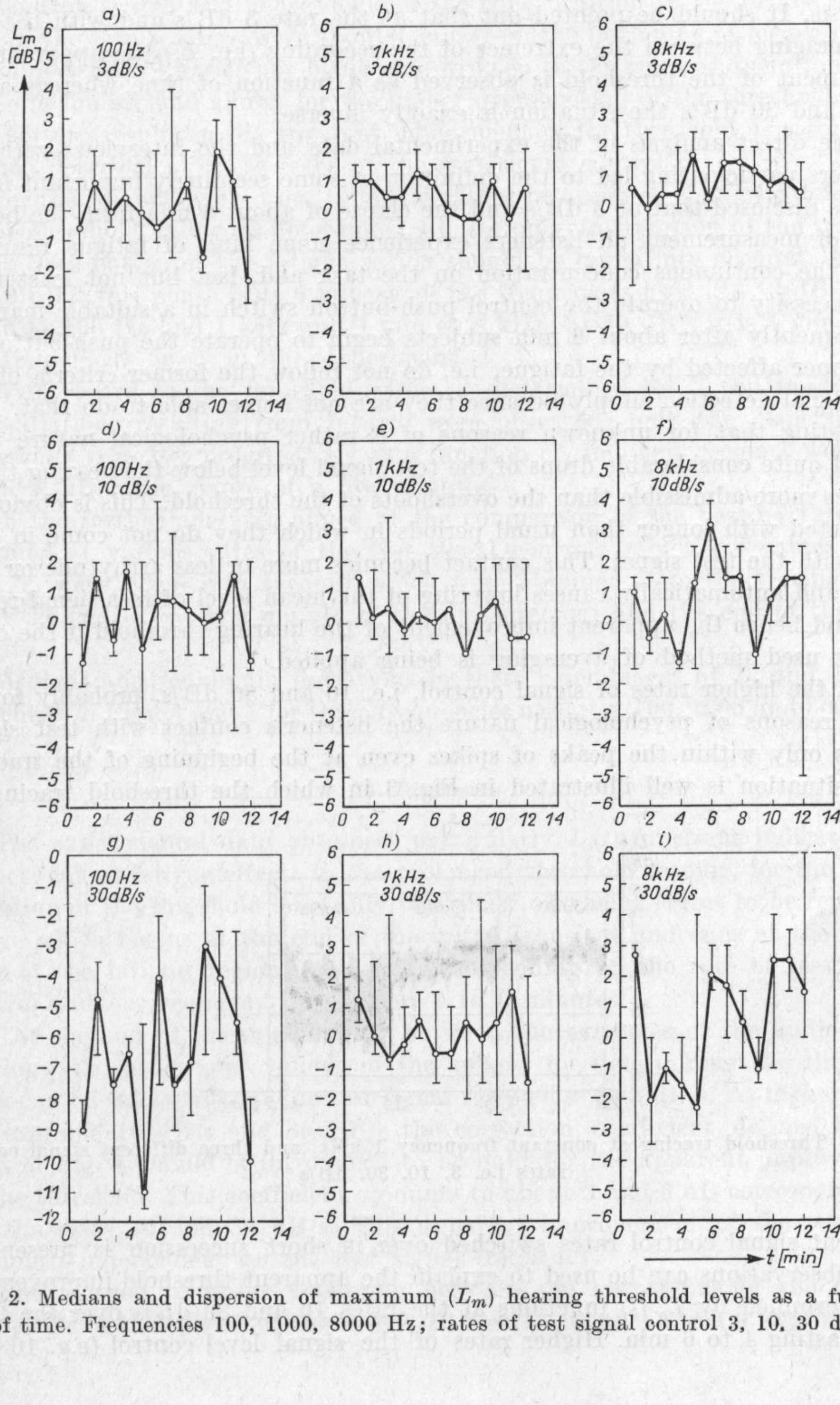

Fig. 2. Medians and dispersion of maximum (L_m) hearing threshold levels as a function of time. Frequencies 100, 1000, 8000 Hz; rates of test signal control 3, 10, 30 dB/s

cided which phase of the obtained functions should be taken for the further analysis. It should be pointed out that at the rate 3 dB/s and with the rule of averaging between the extremes of the recording (i.e. L_s) the apparent improvement of the threshold is observed as a function of time whereas at 10 dB/s and 30 dB/s the situation is exactly inverse.

The direct analysis of the experimental data and the interviews with the listeners participating led to the definition of some seemingly important facts. It was disclosed that at 3 dB/s and the elapse of about 6 min from the beginning of measurement all listeners experience some kind of fatigue resulting from the continuous concentration on the task and, last but not least from the necessity to operate the control push-button switch in a suitable manner. Consequently after about 6 min subjects begin to operate the push-button in a manner affected by the fatigue, i.e. do not follow the former criteria of the test signal detection simply because they are not longer able to do that. It is interesting that for unknown reasons of a rather psychological nature they regard quite considerable drops of the test signal level below the hearing threshold as more admissible than the overshoots of the threshold. This is obviously connected with longer than usual periods in which they do not come in contact with the test signal. This contact becomes more or less arrhytmic or sporadic and automatically causes lowering of the mean level of test signal recorded and hence the apparent improvement of the hearing threshold if the commonly used method of averaging is being applied.

At the higher rates of signal control, i.e. 10 and 30 dB/s, probably for similar reasons of psychological nature the listener's contact with test signal occurs only within the peaks of spikes even at the beginning of the tracing. This situation is well illustrated in Fig. 3 in which the threshold tracing at

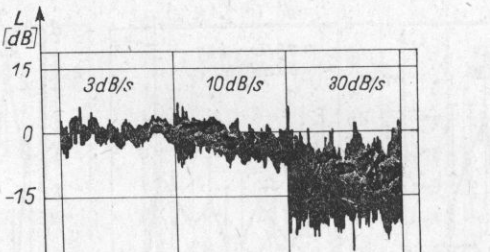

Fig. 3. Threshold tracing at constant frequency 1 kHz and three different signal contro rates i.e. 3, 10, 30, dB/s

different signal control rates switched over in short succession is presented. This observations can be used to explain the apparent threshold improvement as determined by L_s (t) functions at the rates 10 and 30 dB/s over the time span lasting 4 to 6 min. Higher rates of the signal level control (e.g. 10 and

30 dB/s), impose on the subject the necessity of very rapid operation of the push-button switch and hence demand the concentration to the degree higher than at the rate 3 dB/s. After about 4 min from the beginning of measurement the subject finds himself not being able to keep to the rules of operation used at the beginning and allows for the higher overshooting of the threshold level. This in turn results in the apparent impairment of the threshold as a function of time observed at these rates of the test signal control.

For the reasons figured out it should rather be accepted that with reference to the threshold values as determined by L_s, only this portion of the tracings which does not enter the fatigue region should be taken into account. At the rate 3 dB/s this phase lasts 6 min at all the frequencies used. At 10 dB/s it is 6 min at 100 Hz and 1 kHz and 4 min at 8 kHz; at 30 dB/s it is 4 min at all the frequencies used in the experiment.

With regard to the threshold values as determined by L_m no *unidirectional* variations resulting from fatigue were observed; only the dispersion of the results increases progressively as a function of time and becomes well pronounced after the clapse of a few minutes.

In the further analysis, aimed at the comparison of the hearing threshold obtained at various rates of the test signal control, only these values of L_s and L_m were taken into account which were obtained from the tracings between the end of the first minute of the measurement and the end of the fifth minute.

Medians and maximum deviations in these assemblages of L_s and L_m are presented in Figs. 4 and 5 for three frequencies used, i.e. 100, 1000 and 8000 Hz.

4. Discussion

The experimental data obtained, particularly $L_s(t)$ functions indicate that on account of fatigue effects in the prolonged threshold tracing, for the determination of the threshold level only this phase of tracing seems to be representative which begins at the end of the initial transient and ends at the beginning of the fatigue region. This phase, depending on the rate of test signal control and on frequency lasts about 4 to 6 minutes.

The method of linear averaging between the extremes of the audiometric tracings (i.e. peaks and valleys of the spikes) for determining the threshold level can be safely used at the test signal rates close to 3 dB/s. At higher rates, for example 10 dB/s and 30 dB/s the correction coefficient defined by the data in Fig. 4 should be introduced to account for the apparent improvement of the threshold. This coefficient amounts to about 2 and 6 dB correspondingly for the rates 10 and 30 dB/s. This apparent improvement of the threshold is almost independent on the test signal frequency.

The method of linear averaging between the maximums of the tracing (i.e. peaks of the spikes) at the rate 3 dB/s gives about 0.5 to 1.0 improvement

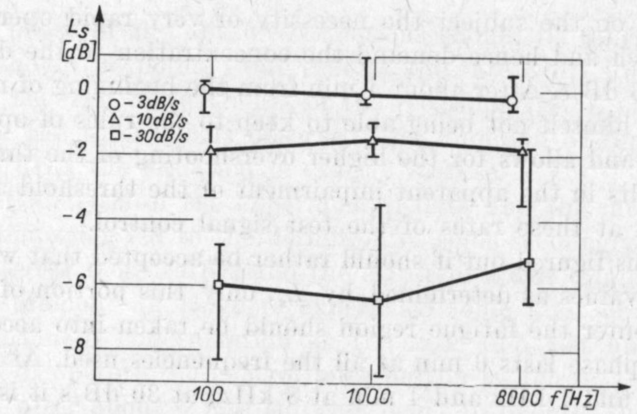

Fig. 4. Medians and deviations of L_s averaged over 4 min of the threshold tracings

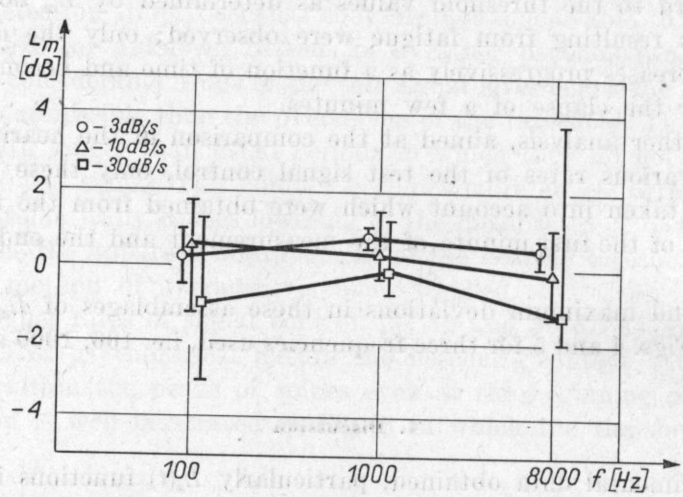

Fig. 5. Medians and deviations of L_m averaged over 4 min of the threshold tracings

of the threshold as compared with the threshold obtained from the linear averaging between the extremes of the tracing. In normal practice this discrepancy is not significant and it can be assumed that at the rate 3 dB/s both methods of reading the tracings are acceptable.

The significant and valuable feature of the method of averaging between the maximums of the tracings is that at higher test signal rates, i.e. 10 and 30 dB/s the threshold is determined directly without the necessity to be corrected by any correction coefficients. As a matter of fact the apparent threshold improvement with this method of interpretation is observed only at 30 dB/s and does not exceede 1 dB. Also, as it is clear from Fig. 2, the threshold thus determined is less dependent on the duration of experiment, at least with regard to the mean value. Only the dispersion obviously increases with time.

It may also be pointed out that the long term variations of L_s at low rates of the test signal control (3 dB/s) and all high rates (10 dB/s and 30 dB/s) go opposite to each other (Fig. 1). This observation suggests that there possibly exists some intermediate rate of signal control at which these variations do not show or are not significant. Inferred from the interpolation of the results obtained at the rates 3 dB/s and 10 dB/s this intermediate rate with possibly lowest time influence on the mean value of the tracing should amount to about 6 dB/s. This conclusion is in agreement, with some experimental data which have not been published so far [11].

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